GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ______

Project No. E-21-J07 R5962-AA7 GTRC/GIT DATE 10/4/85

Project Director: Dr. D.T. Paris School/XXX EE

Sponsor: Naval Coastal Systems Center Panama City, Florida 32407

Type Agreement: Delivery Order No. 0007 Under IQC N61331-85-D-0025 (OCA File 93)

Award Period: From 9/13/85 To 3/31/86 (Performance) 3/31/86 (Reports)

Sponsor Amount:

	This Change	Total to Date
Estimated:	$	$ 102,095.00
Funded:	$ 102,095.00	$ 102,095.00

Cost Sharing Amount: $ ______ Cost Sharing No: ______

Title: Unmanned Hyperbaric Breathing Apparatus Testing and Engineering

ADMINISTRATIVE DATA

OCA Contact R. Dennis Farmer ext. 4820

1) Sponsor Technical Contact:

Dr. Gary KeKelis
Code 4130
Naval Coastal Systems Center
Panama City, Florida 32407-5000
(904) 234-4281

2) Sponsor Admin/Contractual Matters:

Mr. Thomas A. Bryant
Office of Naval Research
Resident Representative
206 O'Keefe Building
Georgia Institute of Technology
Atlanta, Georgia 30332-0490 (404) 881-4374

Defense Priority Rating: DO-C9

Military Security Classification: Unclassified
(or) Company/Industrial Proprietary: ______

RESTRICTIONS

See Attached Govt. Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with Georgia Tech is less than $5,000.00 with prior contracting officer approval.

COMMENTS:

(Subcontracted to Duke University Medical Center)

COPIES TO:

SPONSOR'S I. D. NO. 02.103.001.86.002

Project Director	Procurement/GTRI Supply Services	GTRC
Research Administrative Network	Research Security Services	Library
Research Property Management	Reports Coordinator (OCA)	Project File
Accounting	Research Communications (2)	Other Jones

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 9/23/86

Project No. E-21-J07 School/~~Lab~~ EE

Includes Subproject No.(s) N/A

Project Director(s) D.T. Paris GTRC / ~~GIT~~

Sponsor Naval Coastal Systems Center Panama City, Florida 32407

Title Unmanned Hyperbaric Breathing Apparatus Testing and Engineering

Effective Completion Date: 3/31/86 (Performance) (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [X] Final Invoice or Final Fiscal Report
- [X] Closing Documents
- [X] Final Report of Inventions Questionnaire sent to P.I.
- [X] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Continues Project No. Continued by Project No.

COPIES TO:

Project Director
Research Administrative Network
Research Property Management
Accounting
Procurement/GTRI Supply Services
Research Security Services
Reports Coordinator (OCA)
Legal Services

Library
GTRC
Research Communications (2)
Project File
Other I. Newton
R. Embry
A. Jones

E-21-J07

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF ELECTRICAL ENGINEERING
ATLANTA, GEORGIA 30332

LEPHONE: (404) 894-2902

October 23, 1985

Dr. Gary Kekelis
Code 4130
Naval Coastal Systems Center
Panama City, FL 32407-5000

SUBJECT: Monthly Status Report
Project Director - D. T. Paris
Contract No. N61331-85-D-0025
"NCSC Omnibus R&D Program"
Period Covered - September 13, 1985 - September 30, 1985

Dear Dr. Kekelis:

The subject report is forwarded in conformance with the contract specifications. A monthly report is included for delivery order #0007 for the period - 9/13/85 - 9/30/85.

Should you have any questions or comments regarding this report, please contact Mrs. Cindy Meyer at (404) 894-2961.

Sincerely,

Demetrius T. Paris
Professor and Director

DTP/pm

Addressee: 2 copies
cc: Tom Bryant, ONR
OCA (2)

Monthly Progress/Status Report

NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N61331-85-D-0025

Period Covered: 13 September to 30 September 1985

Order Number: 0007 Title: Unmanned Hyperbaric Breathing Apparatus Testing and Engineering

Task Leader: R. D. Vann

Institution: Duke University Medical Center

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST MONTH

The Unmanned Breathing Apparatus Test System (UBATS) was moved from Foxtrot chamber (maximum depth = 1000 fsw) to Golf chamber (maximum depth = 3600 fsw). The instrumentation for UBATS was set up at the Golf console and planning was initiated for an operator efficient control panel. Design for a water conditioning system and a pressure transducer calibration system was started. Equipment and supplies were ordered for these systems. Enclosed are schematics for the UBATS arc and the amplifiers for UBATS instrumentation.

B. WORK SCHEDULE STATUS

On schedule.

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT MONTH

Complete design and equipment aquisition for water conditioning system.

Complete design and equipment aquisition for pressure transducer system.

Complete all other equipment and supplies aquisition.

Design and install a work/rest cycle control system.

Complete design and installation of UBATS instrumentation panel.

C. (continued)

Design and install the structural support for UBATS arc.

Modify Delta chamber's external ECU for use in the water conditioning system.

Modify data aquisition and data analysis software.

Start installation of water conditioning system and pressure transducer calibration systems.

D. PROBLEM AREAS

None.

E. FUNDS EXPENDED

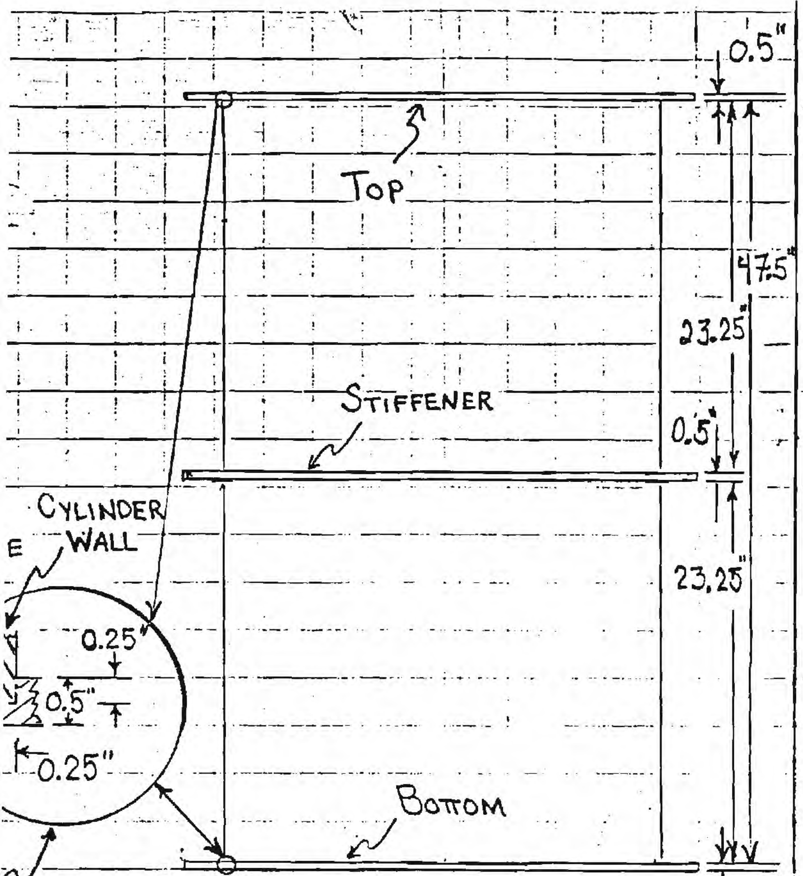
To Date: $17,038

This Month: $17,038

Funds Remaining: $81,882

Percent of Funds Expended: 17%

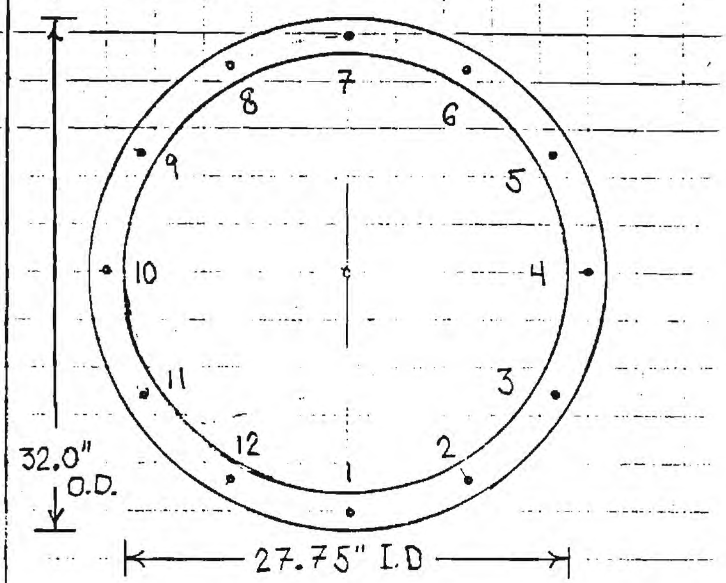
Percent of Task Completed: Testing has not been started.

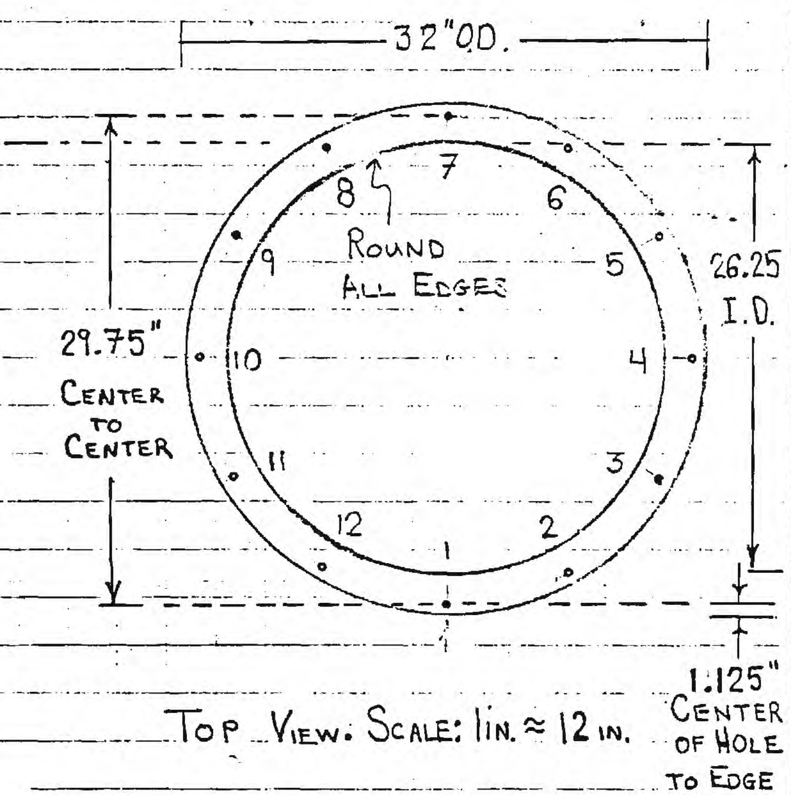


Side View.
Scale: 1 in. ≈ 12 in.

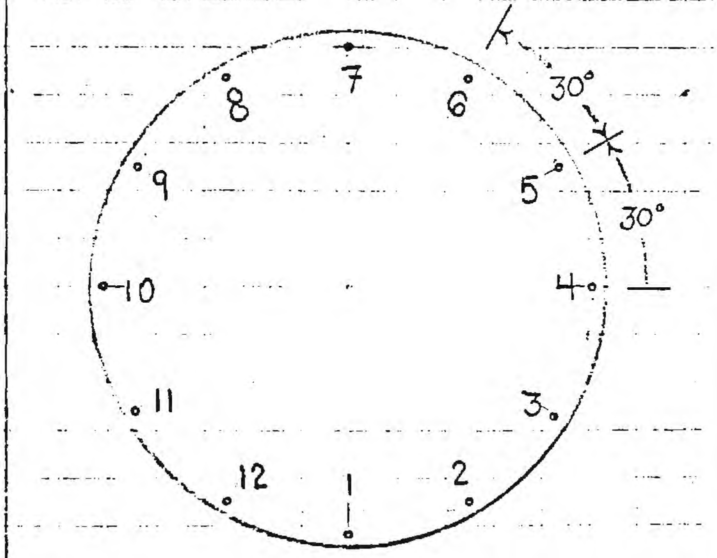
Detail of Top & Bottom Joints.
Scale: 1" ≈ 2"

Detail of Stiffener.
Scale: 1 in. ≈ 12 in.





Top View. Scale: 1in. ≈ 12 in.



Bottom View. Scale: 1 in. ≈ 12 in.

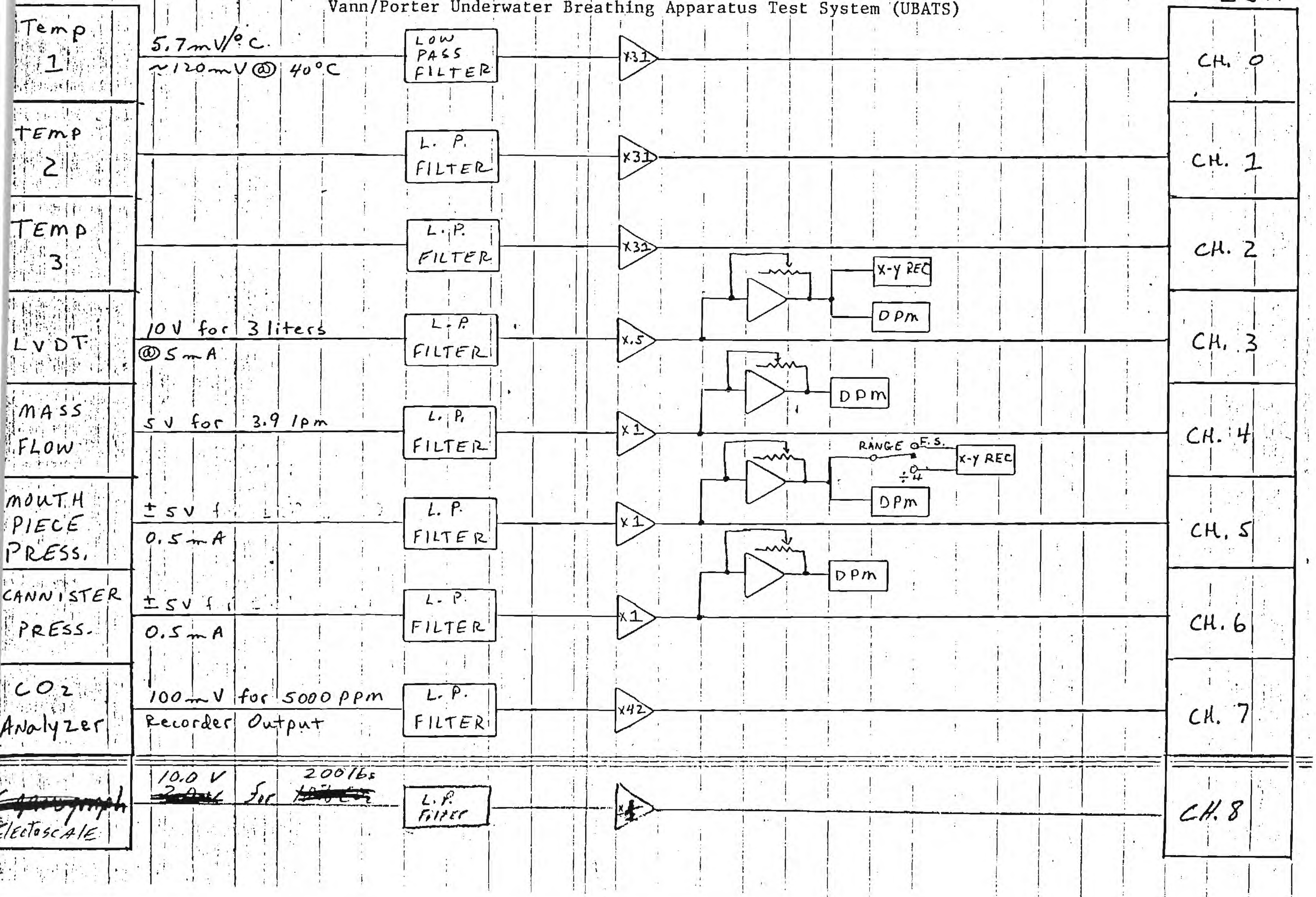
Note: All demensions to be as shown; Drawing scale approimate. Bolt holes to be in same circumferential positions. All holes 9/32" dia.

UBATS Arc, Mk II

Design: S.V. Porter	Date: 16 Sept., 198
Scale: As shown.	

ELECTRONICS BLOCK DIAGRAM

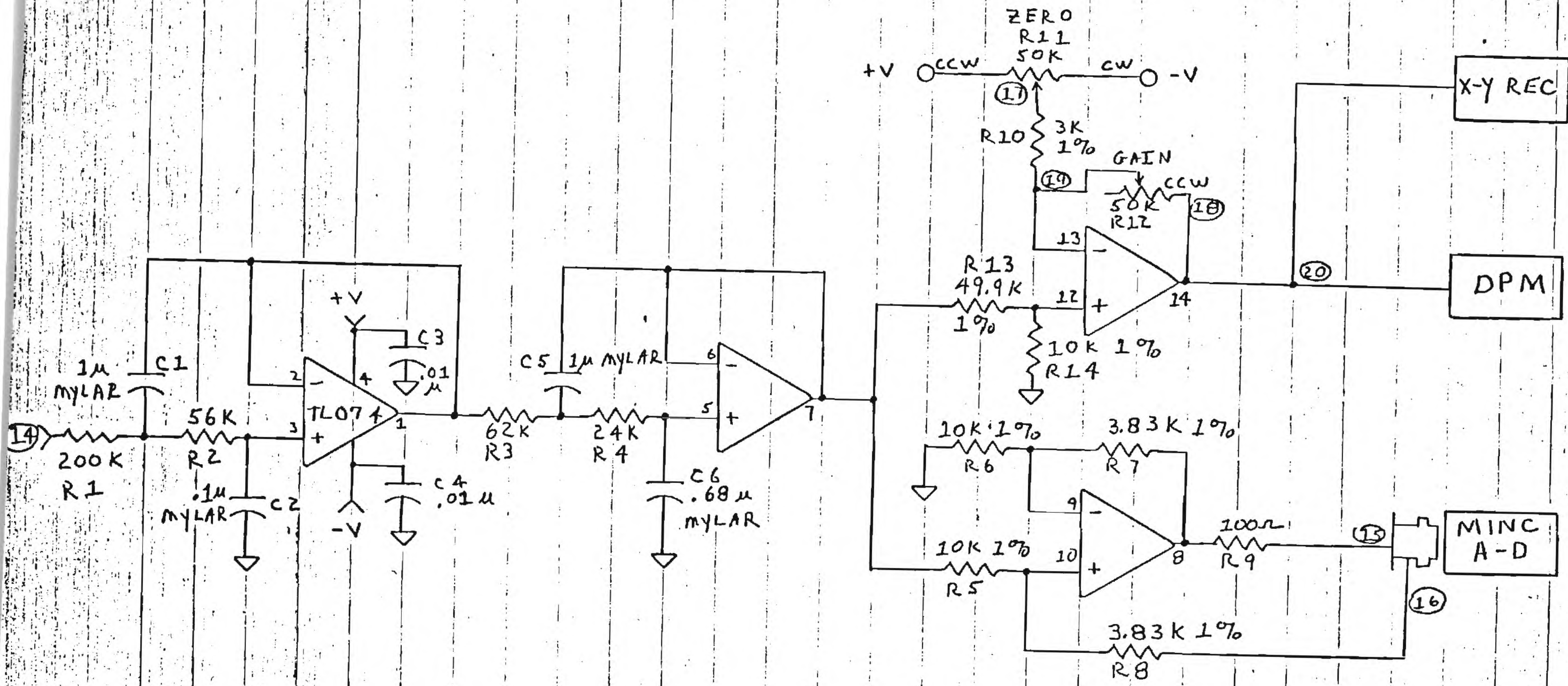
Vann/Porter Underwater Breathing Apparatus Test System (UBATS)



L V D T

for Vann/Porter UBATS Study

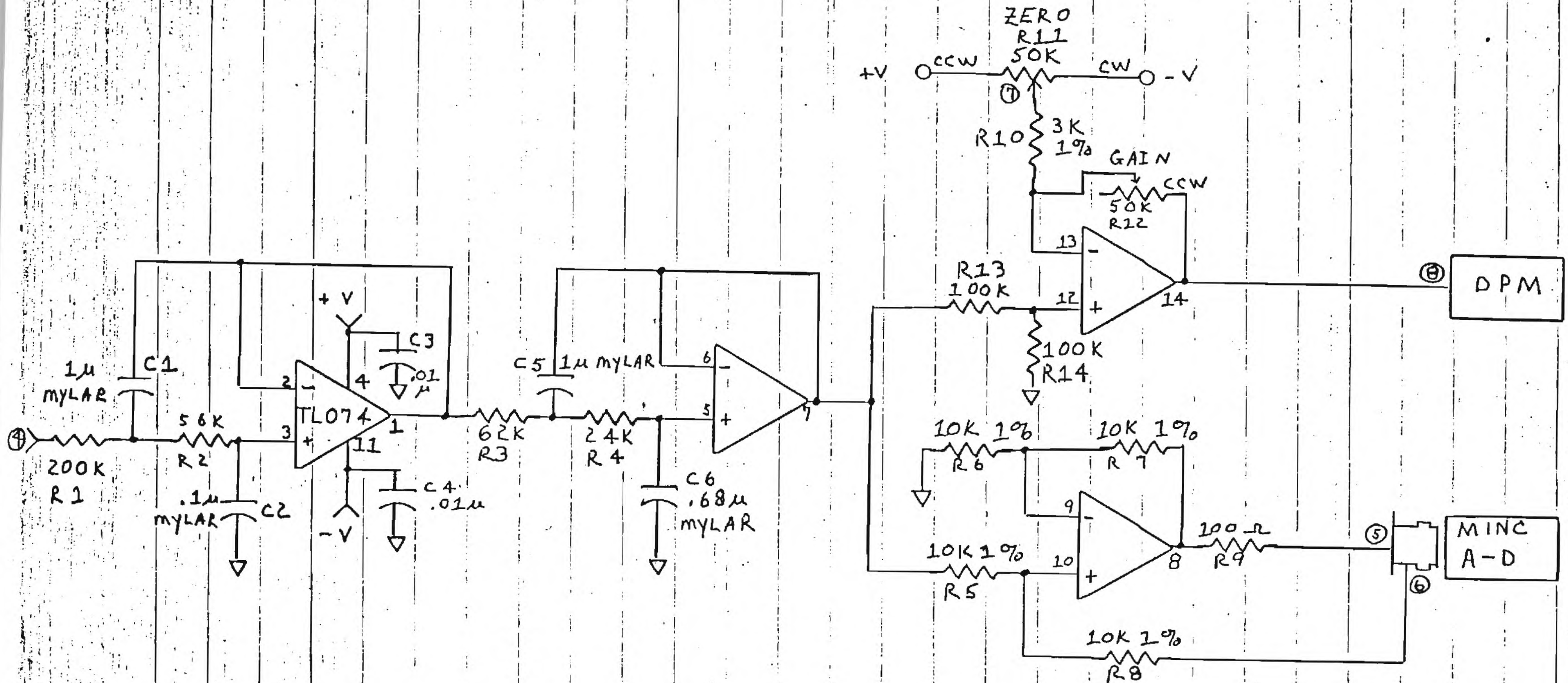
Jul 84



Resistors are ¼W 5% unless otherwise indicated

M A S S   F L O W

for Vann/Porter UBATS Study   Jul 84

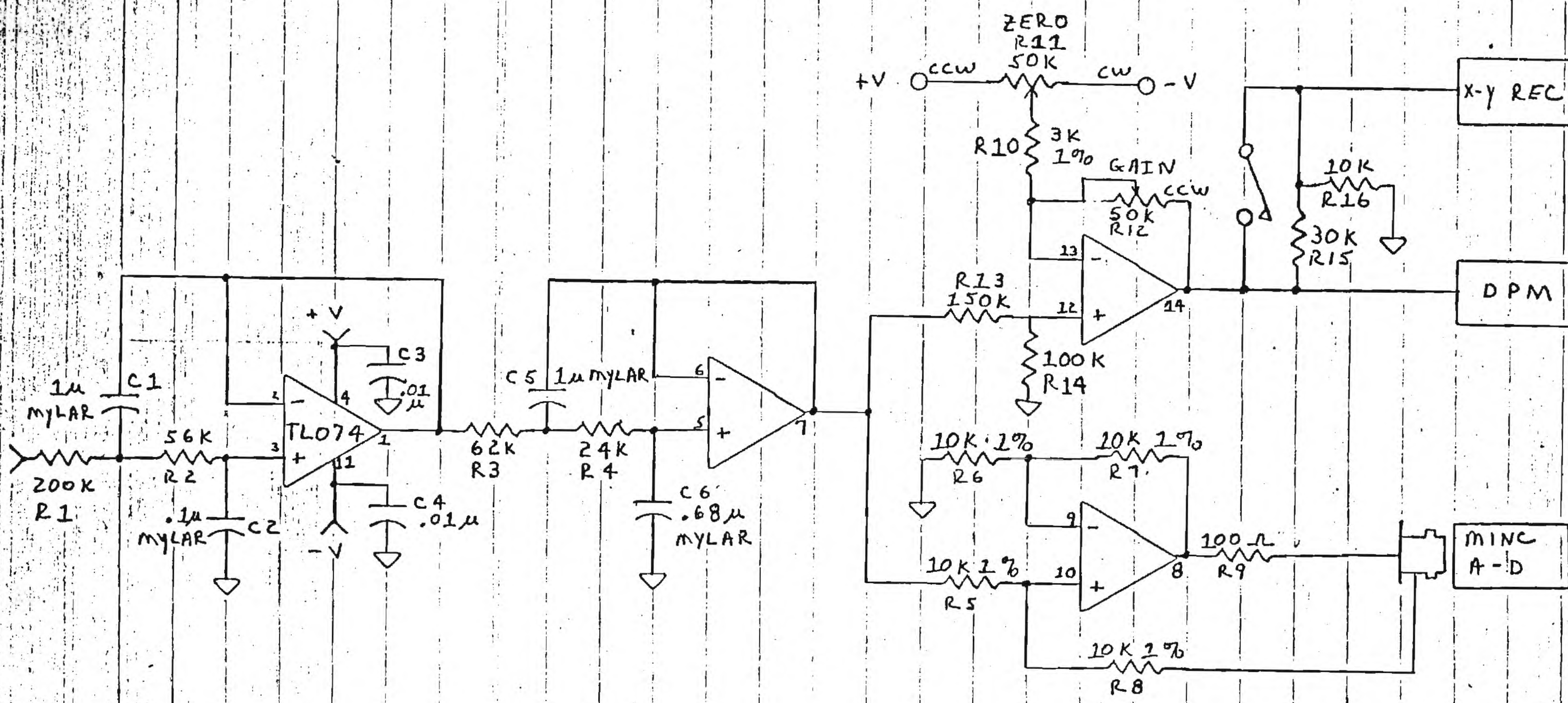


Resistors are ¼W 5% unless otherwise indicated

M O U T H P I E C E P R E S S U R E

for Vann/Porter UBATS Study

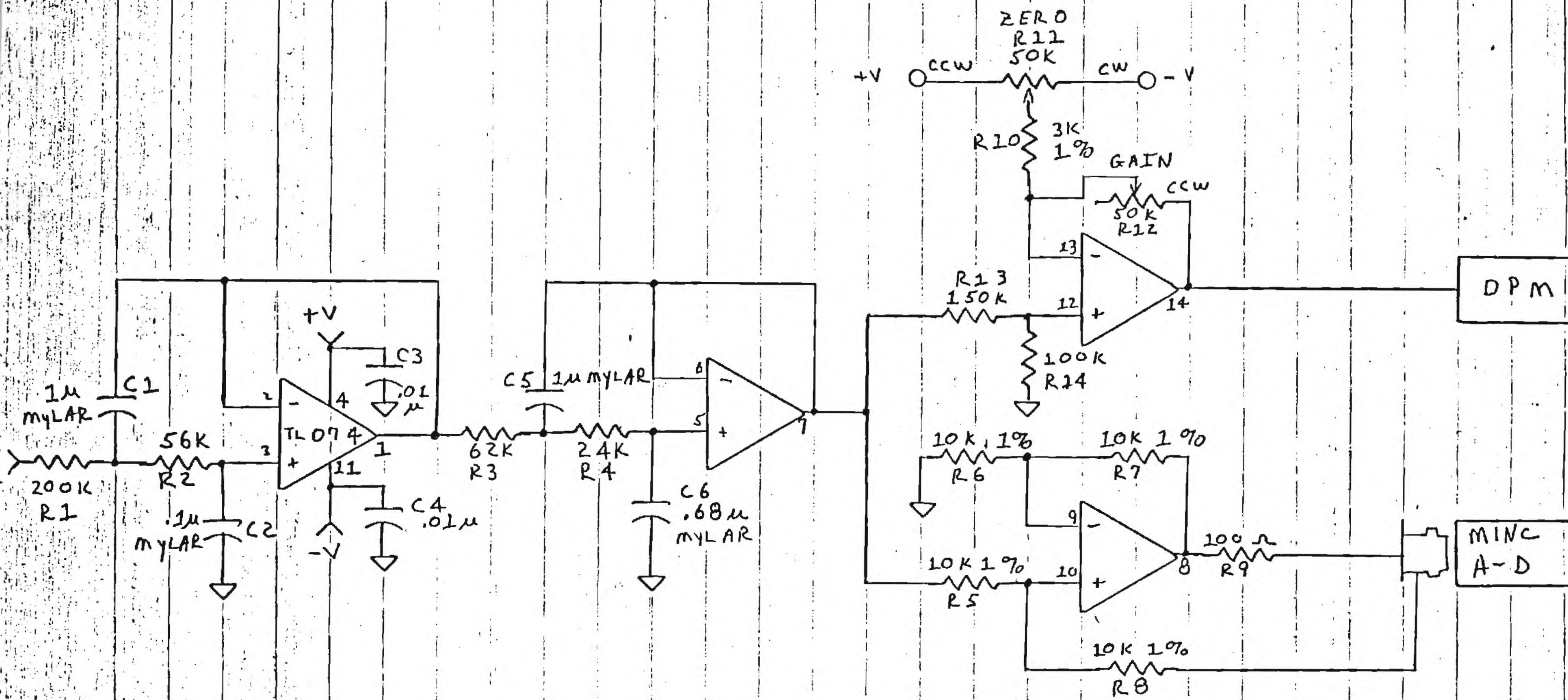
Jul 84



Resistors are ¼W 5% unless otherwise indicated

CANNISTER PRESSURE

for Vann/Porter UBATS Study   Jul 84

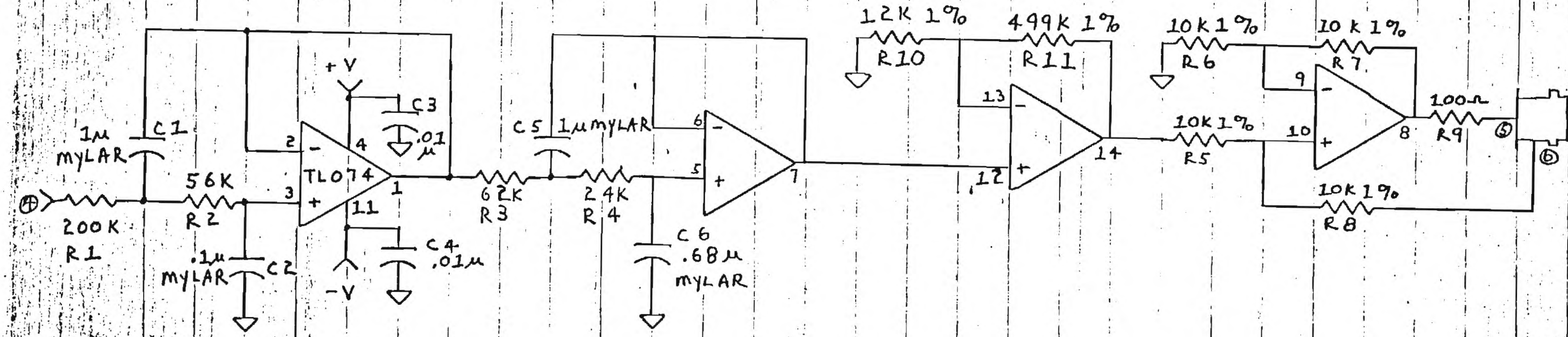


Resistors are ¼W 5% unless otherwise indicated

C O 2 A N A L Y Z E R

for Vann/Porter UBATS Study

July 84

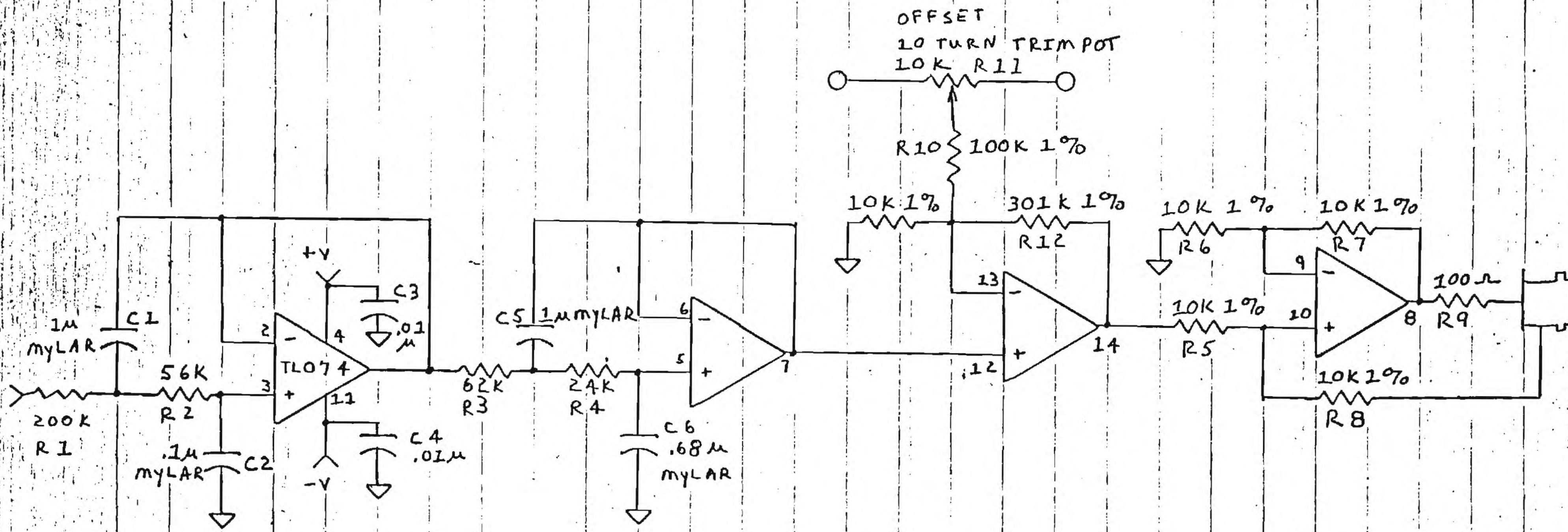


Resistors are ¼W 5% unless otherwise indicated

3 TEMPERATURE CHANNELS

for Vann/Porter UBATS Study

Jul 84

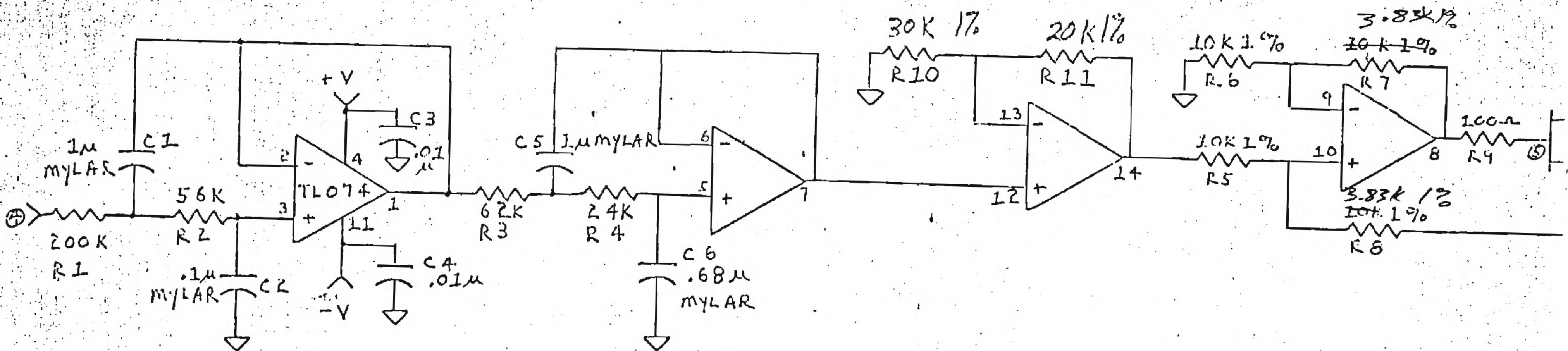


Resistors are ¼W 5% unless otherwise indicated

[redacted]

ELECTROSCALE

for Vann/Porter UBATS Study



Resistors are ¼W 5% unless otherwise indicated

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF ELECTRICAL ENGINEERING
ATLANTA, GEORGIA 30332

.EPHONE: (404) 894-2902

November 12, 1985

Dr. Gary Kekelis
Code 4130
Naval Coastal Systems Center
Panama City, FL 32407-5000

SUBJECT: Monthly Status Report
Project Director - D. T. Paris
Contract No. N61331-85-D-0025
"NCSC Omnibus R&D Program"
Period Covered - October 1, 1985 - October 31, 1985

Dear Dr. Kekelis:

The subject report is forwarded in conformance with the contract specificatons. A monthly report is included for delivery order #0007 for the period 10/1/85 - 10/31/85.

Should you have any questions or comments regarding this report, please contact Mrs. Cindy Meyer at (404) 894-2961.

Sincerely,

Demetrius T. Paris
Professor and Director

DTP/pm

Addressee: 2 copies
cc: Tom Bryant, ONR
OCA (2)

Monthly Progress/Status Report

NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N61331-85-D-0025

Period Covered: 1 October to 31 October 1985

Order Number: 0007 Title: Unmanned Hyperbaric Breathing Apparatus Testing and Engineering

Task Leader: R. D. Vann

Institution: Duke University Medical Center

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST MONTH

Preparation of the Unmanned Breathing Apparatus Test System (UBATS) for the required testing was continued this past month. Design work for the water conditioning system, the pressure transducer calibration system, the automatic work/rest cycle control system, the instrumentation control panel, and the structural support for the UBATS arc was completed and the necessary parts and equipment were ordered. Aquisition of all other necessary supplies and equipment was completed. The heat exchanger in Delta chamber's external ECU was isolated and prepared for use in the UBATS water conditioning system. The support structure for the UBATS arc was fabricated and installed in Golf chamber. The water conditioning system's motor/pump was mounted. The wiring for the instrumentation outside the chamber, the control panel, the computer, and the respiratory pump was completed. The respiratory pump was mounted. Enclosed are schematics for the water conditioning system, the pressure transducer calibration system, the instrumentation control panel, the automatic work/rest cycle control system, and the structural support for the UBATS arc.

Seven hundred pounds of LiOH were ordered from Polyresearch, Deerpark, NY. This LiOH has an absorption capacity of 0.7 g CO2/ g LiOH (mil spec). Two weeks later, Jim Middleton reported that NCSC has about one hundred fify pounds of LiOH with an absorption capacity of 0.8 g CO2/ g LiOH. The LiOH with the 0.8 absorption capacity was offered to Duke University for comparison testing with the 0.7 g CO2/g LiOH grade LiOH ordered from Polyresearch. At this time, the order from Polyresearch was cut to two hundred pounds. One week later, it was determined that obtaining the 0.8 g CO2/ g LiOH grade LiOH would not be cost effective. After consulting with Jim Middleton, a decision was made to test the LiOH from Polyresearch as soon as possible. A decision concerning the testing of the 0.8 g CO2/ g LiOH grade LiOH will be made after analyzing those initial results.

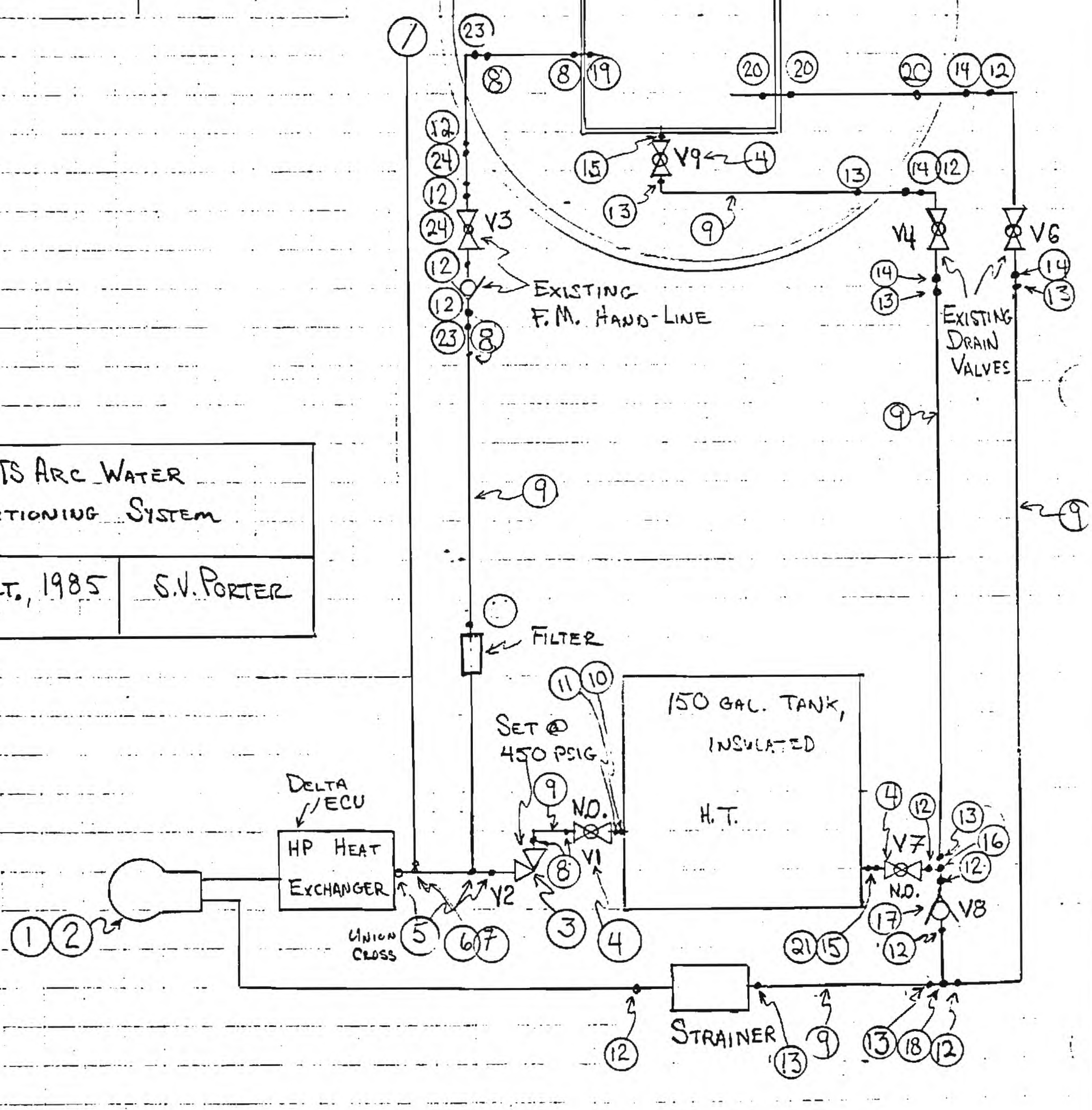
B. WORK SCHEDULE STATUS

On schedule.

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT MONTH

1) Arc installation. (SP, BS)
2) Water conditioning system installation.
   a) Plumbing. (SP, BS)
   b) Testing. (SP)
3) Mount holding tank. (BS)
4) Mount computer terminal. (MN, BS)
5) Mount x-y plotter. (MN, BS)
6) Modify amplifier for digital scale. (MN)
7) Install automatic work/rest control system. (MN)
   a) CO2 addition system
   b) Modify DC motor controller
8) Test instrumentation. (MN)
   a) LVDT
   b) Mass Flow
   c) Hygrometer
   d) Pressure transducers
   e) Respiratory pump
   f) Heat tapes
   g) Temperature probes
   h) Digital scale
   i) CO2 analyzer
9) Modify software. (MN)
10) Test software. (MN)
11) Mount temperature boxes. (MN)
12) Canister design. (SP)
13) Design manekin test rack. (SP)
14) Fabricate manekin test rack. (BS)
15) Design test plan. (SP)
16) Install pressure transducer cal. system. (SP, MN)
17) Fabricate canisters. (BS)
18) Change oil in respiratory pump. (SP)
19) Modify LVDT to change x-y plotter direction. (MN)
20) Install CO2 analyzer calibration system. (MN, SP)
21) Change antifreeze in chiller. (SP)
22) Install and wire inside instrumentation. (MN)

~LE MODE	V2	V3	V4	V6	V8
Fill Arc	C	O	C	C	–
Recirc. Arc	C	O	C	O	C
Empty Arc w/ Pump	O	C	C	O	C
Recirc H.T.	O	C	C	C	O
Empty Arc w/o Pump	C	C	O	C	–

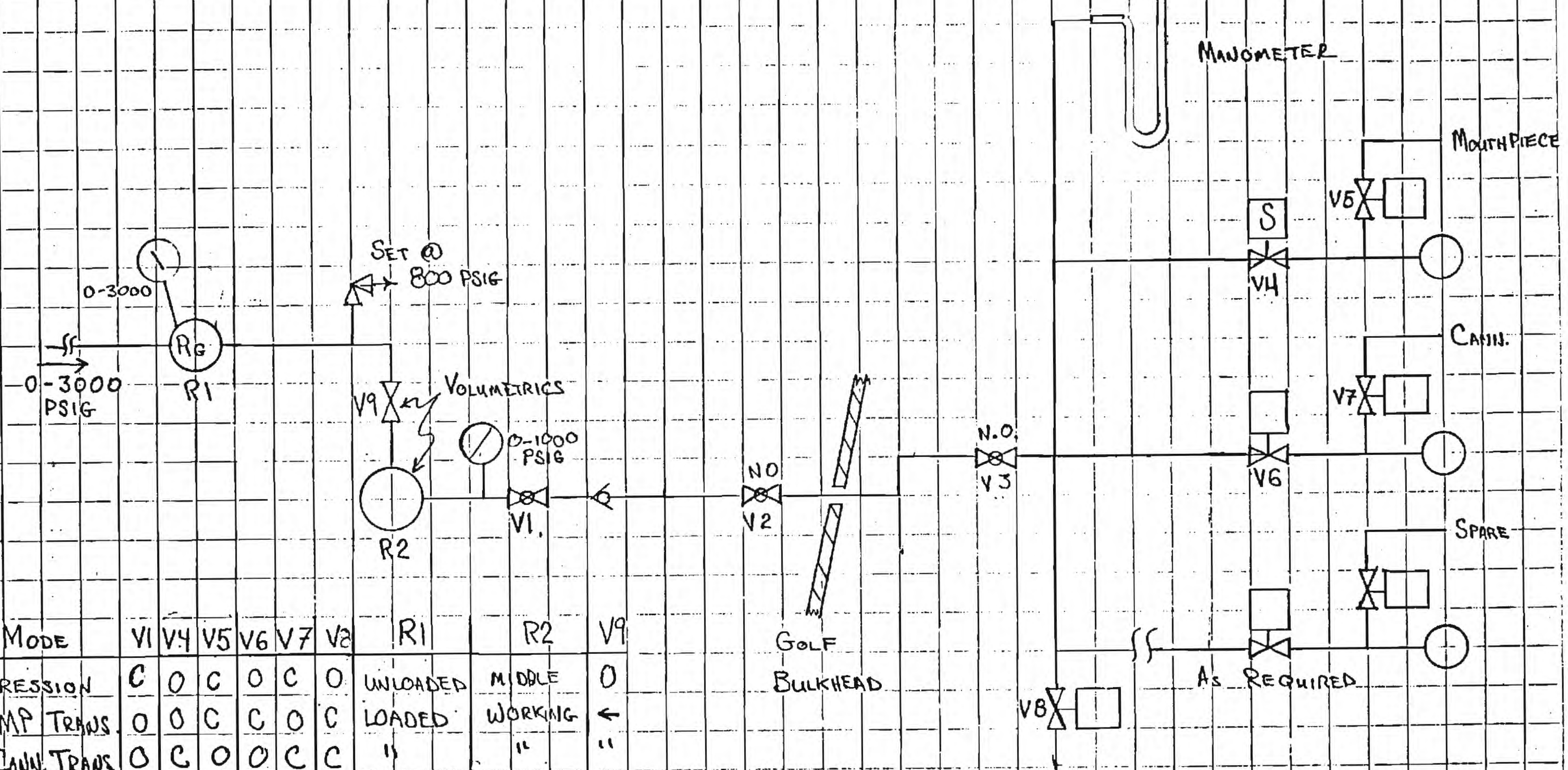


UBATS Arc Water Conditioning System	
8 Oct., 1985	S.V. Porter

G = GANN
R = RAC. V. & F.

RECEIVED	No.	QUAN	DESCRIPTION	DATE ORDERED	PRICE/UNIT	TOTAL PRICE	
	1	1	HP PUMP, HYDRA CELL, D10-S (CENTER BOLT) WP 1200 PSI, 10 GPM, 7/8" SHAFT w/ 3/16" KYWY.	✓			
	2	1	ELEC. MOTOR, 7½ HP, 1725 RPM	✓			
	3	1	PRESSURE CONTROL UNLOADER VALVE, HYDRA CELL, C10, ADJUSTABLE 0 TO 1000 PSI UNLOADING	✓			
	4	5	WHITEY 65 BALL VALVES 1"	✓ RAC V+F			
+2	5	卌I	3/4" MNPT NIP, HEX (2) FF-B-3/4	3.29 ✓			
+1	6	II	3/4" FNPT UNION CROSS ✓ NC	RAC V+F 28.08 ✓			
	7	I	3/4" NPT REDUCING BUSHING TO 1/4" PTR-B-3/4x1/4	2.73 ✓			
+2	8	卌III	3/4" NPT - #16 JIC NIP ✓ FTX-B-16-12	5.10 ✓			
	9	100 FT	3130 SYNFLEX HOSE	4.33/FT 3.93 ✓	2.79/FT		NOT
	10	I	1¼" - 3/4" REDUCING BUSHING ✓ NC				
	11	III	3/4" MNPT EL CR-B-3/C	11.37 ✓			
+2	12	卌卌II	1" MNPT NIP FF-B-1	5.21 ✓			
+2	13	卌I	1" MNPT - #16 JIC NIP FTB-B-16	5.66 ✓	4.18		NOT
	14	IIII	1½" - 1" REDUCING BUSH PTR-B-1x1 ✓ (NO)				
X	15	IIII	1" MNPT FNPT EL DD-B-1	27.91 ✓			
	16	II	1" FNPT UNION CROSS KKMCO- ✓ (NO)				
X	17	I	1" CHECK VALVE				
	18	~~X~~ 3	1" FNPT TEE MMC-T-1	18.16 ✓			
+2	19	卌	3/4" MNPT - #16 JIC EL CTX-B-16-12	10.91 ✓			
+2	20	卌	1" MNPT - #16 JIC EL CTX-B-16-	17.41 ✓	19.87		NO
	21	I	1¼" - 1" NPT REDUCING BUSH (NC) ✓				
	[illegible]	[illegible]	[illegible]	3.60 ✓ FOR 25			

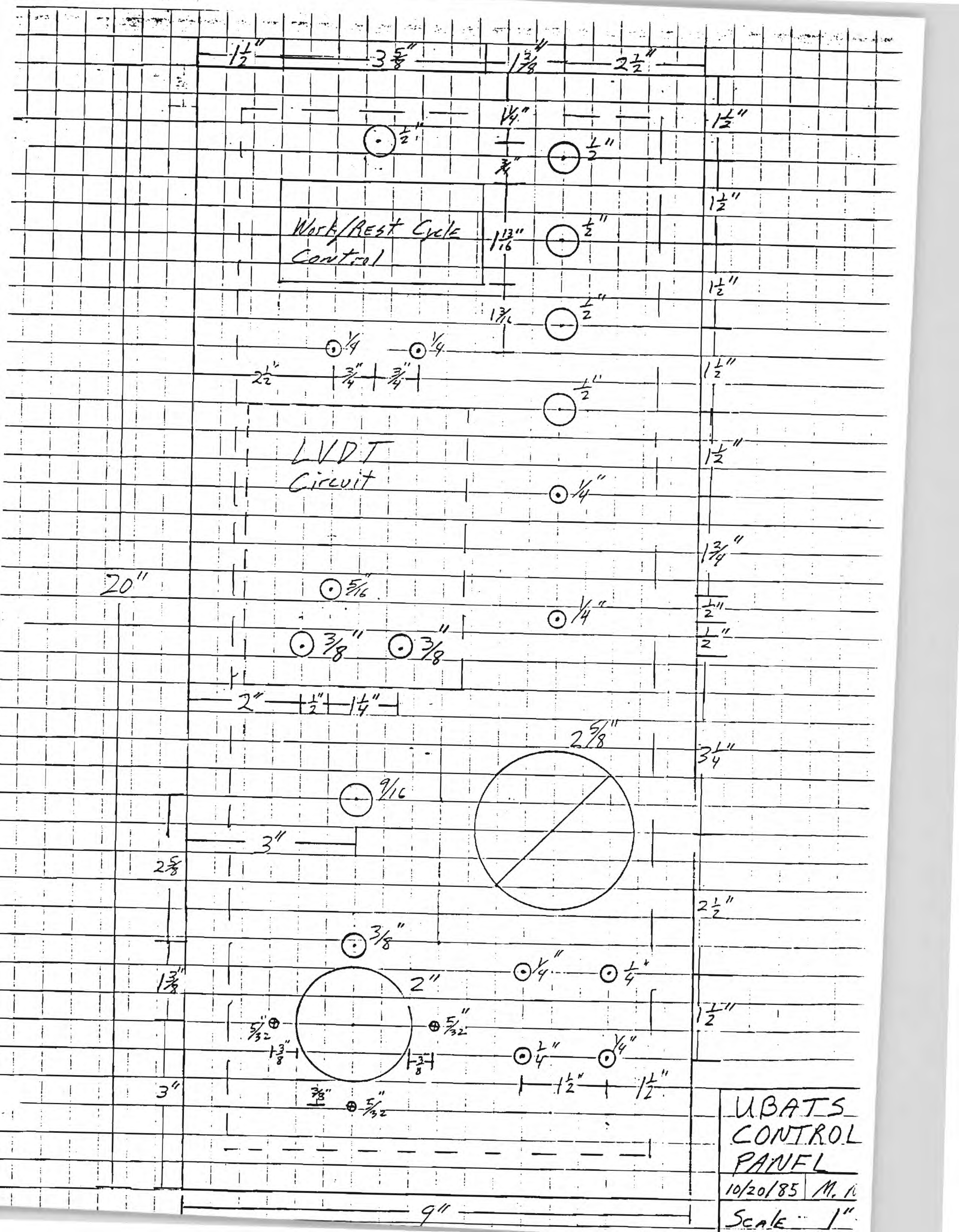
[illegible]CEIVED	No.	QUAN.	DESCRIPTION	DATE ORDERED	PRICE/ UNIT	TOTAL PRICE
	23	11	1" - $\frac{3}{4}$" REDUCING BUSH PTR-B-1 × 3/4	3.34 ✓		
	24	11	1" NPT STREET EL CD-B-1	21.81 ✓		
	25	11	$\frac{3}{4}$" NPT STREET EL CD-B-$\frac{3}{4}$	8.91 ✓		
			DIE 26.79 ✓			
			PUSHER 12.34 ✓			

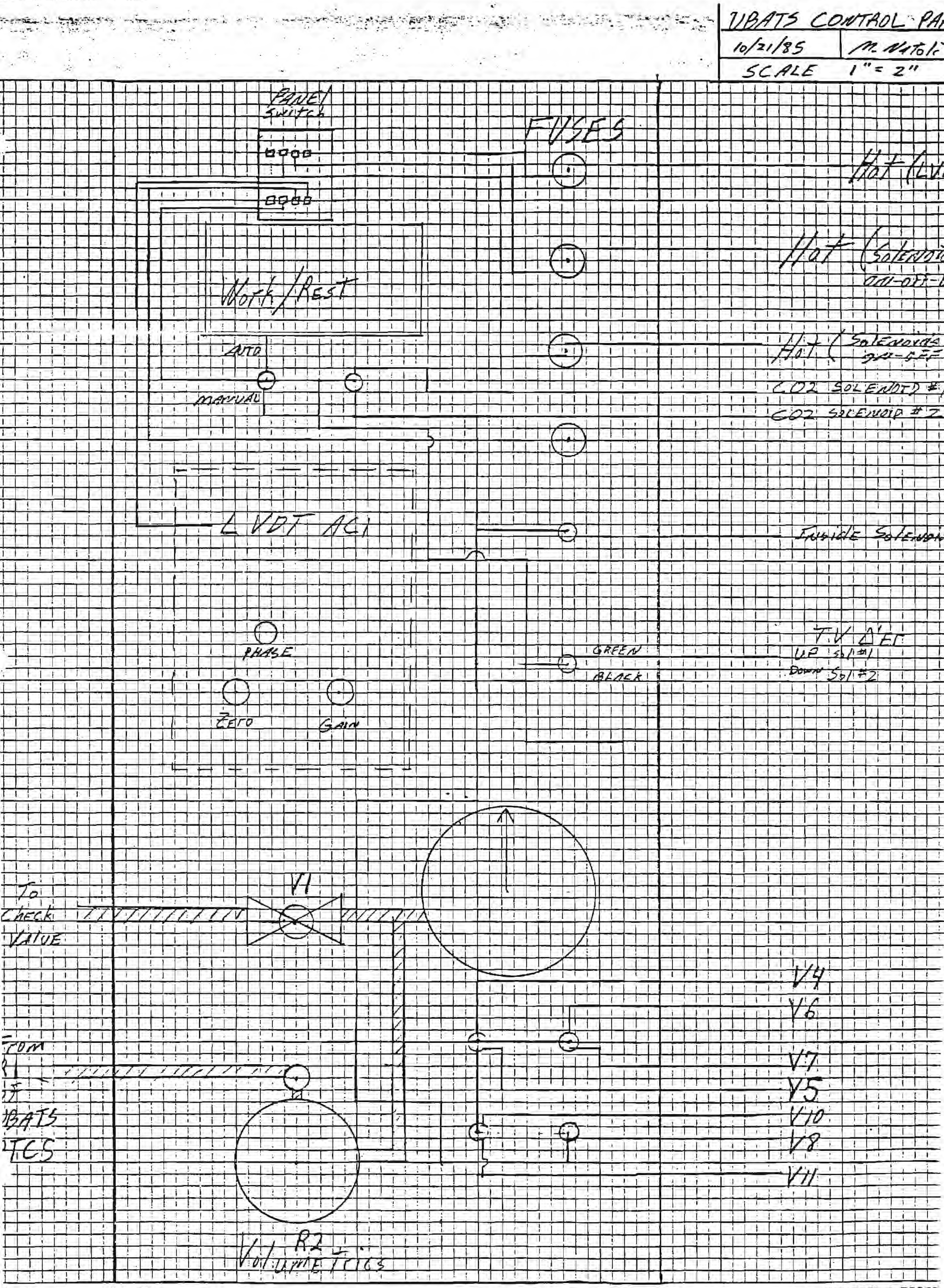


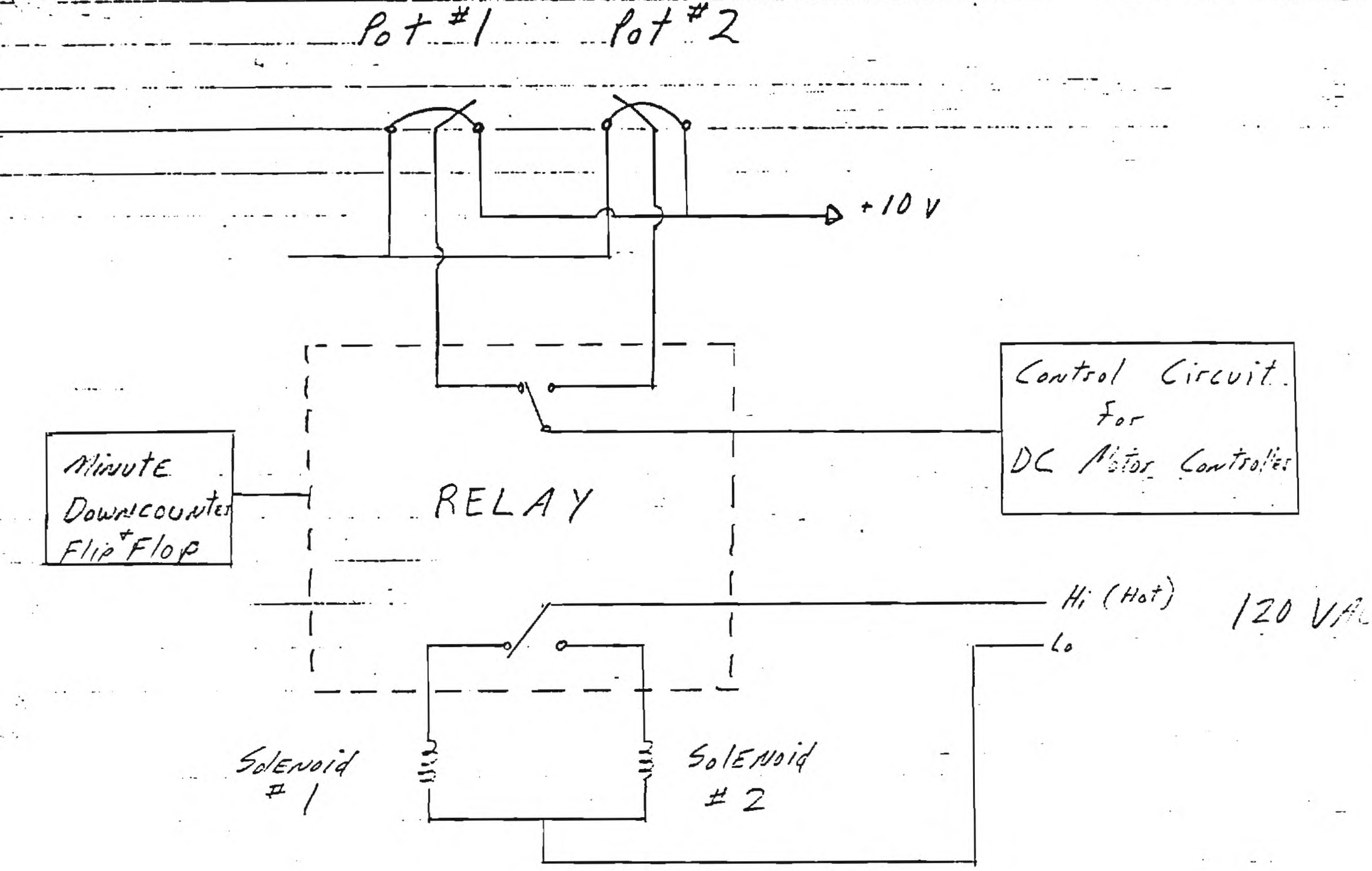
MODE	V1	V4	V5	V6	V7	V2	R1	R2	V9
COMPRESSION	C	O	C	O	C	O	UNLOADED	MIDDLE	O
CAL MP TRANS.	O	O	C	C	O	C	LOADED	WORKING	←
CAL CANN TRANS	O	C	O	O	C	C	"	"	"
TESTING	C	C	O	C	O	O	"	MIDDLE	"
DECOMPRESSION	C	O	C	O	C	O	UNLOADED	"	C

UBATS PRESSURE TRANSDUCER
CALIBRATION SYSTEM

14 OCT., 1985 | S.V. PORTER


Work/Rest Cycle Control
LVDT Circuit
20"
9"
UBATS CONTROL PANEL
10/20/85
Scale: 1"


UBATS CONTROL PAN
10/21/85
M. Natoli
SCALE 1" = 2"
PANEL Switch
FUSES
Hot (LVL
Hot (Solenoid
ON-OFF-D
Work/Rest
AUTO
MANUAL
Hot (Solenoids ON-OFF
CO2 SOLENOID #1
CO2 SOLENOID #2
LVDT ACI
Inside Solenoid
GREEN
BLACK
PHASE
ZERO
GAIN
T.V. Δ'ER
UP Sol #1
Down Sol #2
To Check Valve
V1
V4
V6
From
UBATS
V7
V5
V10
V8
V11
R2
Volumetrics



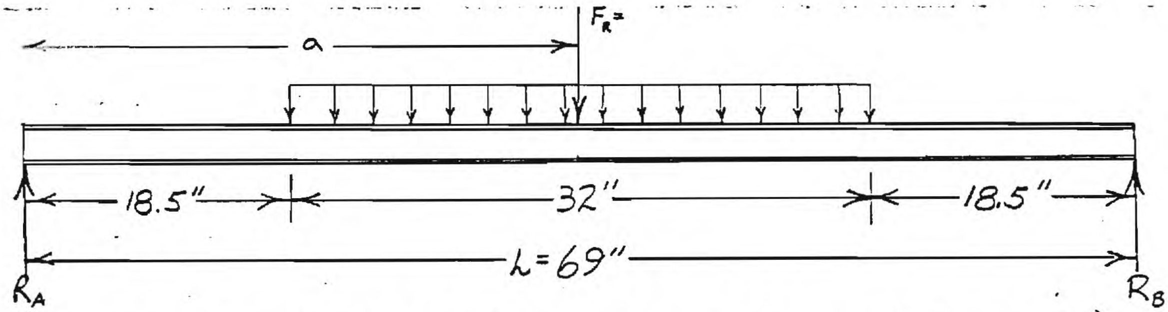
Notes:

1) A solenoid draws 50 mA.
2) At full Load the motor draws 5.2 A.
3) During 4 min. interval Pot #1 and Solenoid #1 are Enable
4) During 6 min. interval Pot #2 and Solenoid #2 are Enable.
5) Cycle should start by manually Enabling Downcounter.
6) Cycle may continue for up to Eight hours.
7) Cycle will be Ended manually.

Work/Rest Cycle Contro	
Design: M. Natoli	Date: 10/8/8-
Notes: Minute downcounter + Flip Fl designed by C-Tek.	

BEAMS:

- ASSUME WEIGHT OF ARC EQUALLY SUPPORTED BY EACH OF 2 BEAMS.
- ASSUME WORST CASE (I.E. CONCENTRATED FORCE AT ℄.
- ASSUME I BEAM OF LENGTH 69"



(EQUATIONS FROM FORMULAS FOR STRESS p. 97 SEC. 1e.)

$R_A = R_B = 700$

$M_{max} = R_A a$ WHEN $a = L/2$ $M_{MAX} = 24150$ #·IN

$\sigma_{DESIGN} \leq \frac{M_{MAX}\, y}{I}$ ASSUME A36 STRUCTURAL STEEL Y.S. = 30 KSI. (STATICS & STRENGTH OF MAT. p 489)

HAVE 4" DEEP × 2.660 IN FLANGE "I" BEAM

$I = 6.0\,IN^4$ $y = 2\,IN$ (M.E. HBK p 12-34)

$\sigma_{DESIGN} = \frac{My}{I} = \underline{\underline{8.05\ KSI}}$ $\underline{\underline{S.F. = 3.73}}$

BEAM DEFLECTION:

MAX. DEFLECTION AT $a = L/2$

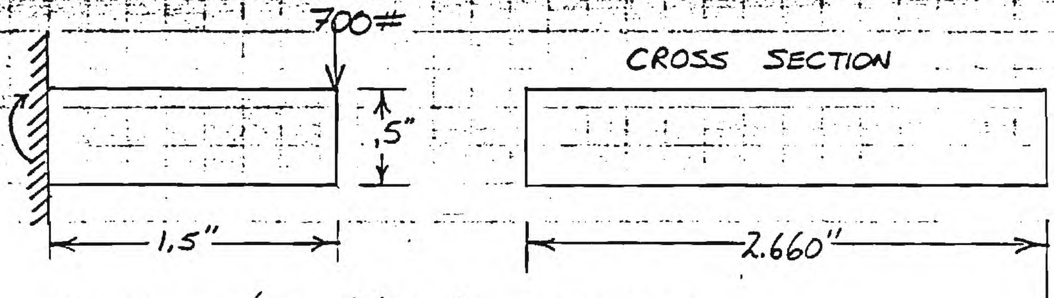
$y_{MAX} = \frac{FL^3}{48EI} = \frac{(1400\#)(69")^3}{(48)(30\times10^6 PSI)(6\,IN^4)}$ ("E" FROM STATICS & STRENGTH OF MATERIALS p 489

$y_{MAX} = .0532$ IN

SHEAR $V = F - R_A = 1400 - 700 = 700\#$

$V_{MAX\ ALLOWABLE} = 11000\#$ ∴ S.F. = 15.7

MODEL DECK LIP AS CANTILEVERED BEAM



$M = Ra = (700\#)(1.5") = 1050\#IN$

$\sigma = \frac{My}{I} = \frac{(1050\#IN)(.25IN)}{\frac{1}{12}(2.66IN)(.5IN)^3} = 9473.7 \text{ PSI}$

ASSUMING A36 STEEL $\qquad$ **S.F. = 3.8**

CHECK SHEAR

$V = 700\#$

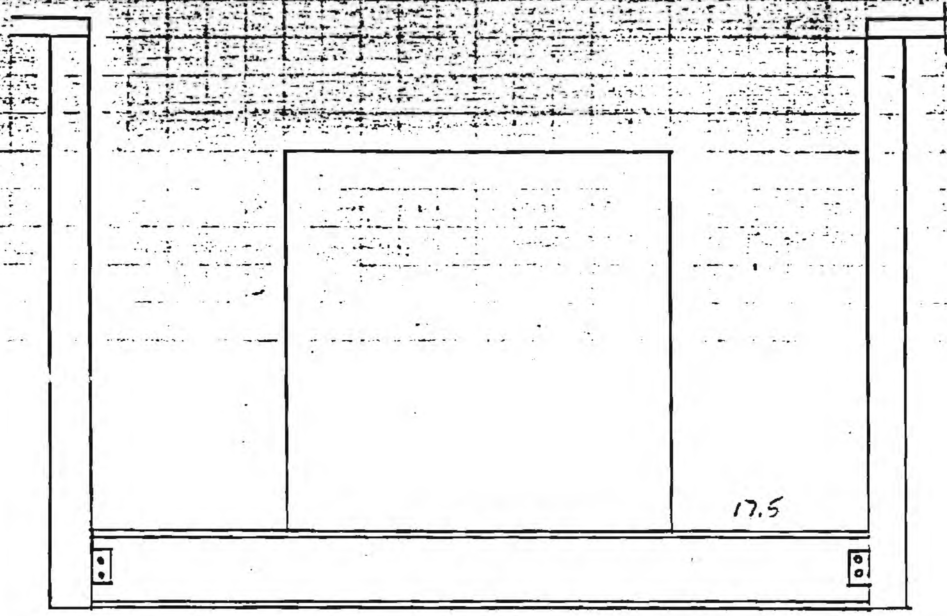
FORMULAS FOR STRESS, p93
α FOR RECTANGLE = 3/2

$\tau_{MAX} = \alpha \, V/A$

$= (3/2)\frac{(700\#)}{(.5")(2.66")} = 789 \text{ PSI}$

τ_{MAX} WITHIN LIMITS

UBATS | SUPPORT STRUCTURE | SI | 9/25/85



FOR 4" DEEP × 2.66" FLANGE "I" BEAM 69" LONG

$W_I = 44.275$ lb

ASSUMING EVEN WEIGHT DISTRIBUTION, THE WEIGHT SUPPORTED BY EACH CHANNEL BEAM IS:

1/4 ARC WEIGHT + 1/2 BEAM WEIGHT ≈ 375 #.

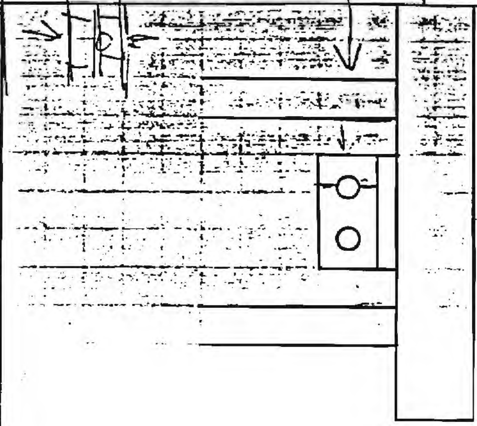
WE HAVE 1" × 2" CHANNEL BEAM $A_{\text{CROSS SECTION}} = .875\ \text{IN}^2$

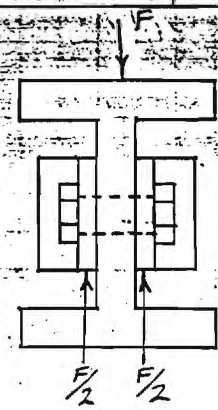
$\therefore$

$\boxed{\sigma = 430\ \#/\text{IN}^2}$

FOR A36 STEEL Y.S. = 36 KSI (STATICS & STRE. pg. 489)

SF = 83.72 BEAM IN STOCK O.K. ✓





ASSUME ONE BOLT IN CALCULATIONS
USE DUPLICATE IN ACTUAL FABRICATION

SHEAR FORCE ON BOLTS: 375# WITH S.F. = 2 $F_{DESIGN} = 750\#$

$\sigma_{SHEAR} = \dfrac{F_{DES}/2}{A} = \dfrac{375}{A}$ $\sigma_{SH} = \sigma_{us}/2$

$\sigma_{YIELD\ SHEAR} = 18\ ksi = \dfrac{375}{A}$ $A = .02\ IN^2$ ASSUME A36 STEEL

$A = .02\ IN^2 = \pi r^2$ $r = .08\ IN$ $\boxed{D = .16\ IN}$ – $0.17\ in$

FAILURE BY BENDING: (ME DESIGN p392)

$M = \dfrac{Ft}{2}$ WHERE F IS SHEARING FORCE
t IS GRIPPING THICKNESS

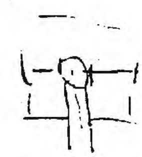
$M = \dfrac{(375\#)(.19 + .25\ IN.)}{2} = .22\#\ IN$ (WEB THICK. – MARKS (12-34)
ASSUME 1/4" THICK ANGLE

$\sigma = \dfrac{M}{I/c} = \dfrac{(.22\#\ IN)}{(\frac{1}{4}\pi r^4)/r} = \dfrac{(.22\#\ IN)}{\frac{1}{4}\pi (r)^3}$ I/c IS SECTION MC.

$\sigma_{MAX} = 36\ ksi = \dfrac{.22\#\ IN}{\frac{1}{4}\pi (r)^3}$ $r = .0198\ IN$ $D = .04\ IN$ .05 in

FAILURE OF BRACKET:

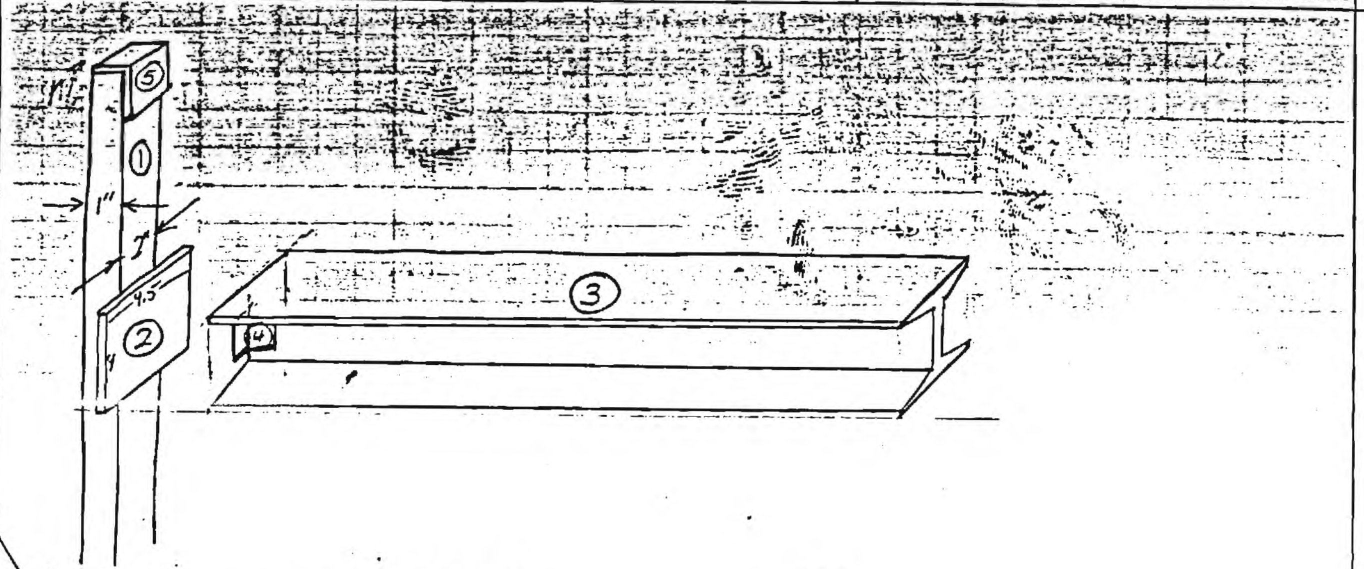
$\sigma = \dfrac{F}{A} = \dfrac{F}{td} = \dfrac{375}{(.19 + .25)(d)}$



$\sigma_{YIELD} = 36\ ksi$ $d = .024\ IN$

SPACE BOLT AT LEAST 1.5 DIAMETERS AWAY FROM MARGIN

USE $\frac{1}{4}$" – 20 T.P.I. BOLTS



	#	SIZE
PART 1	4	1" X 2" X .25" X 44.5" CHANNEL BEAM
PART 2	4	4.5" X 12" X .25"
PART 3	2	? X 4" DEEP X 2.66" FLANGE "I" BEAM
PART 4	8	2" X 2" X .25" X 3" ANGLE
PART 5	4	1.25" X 1.25" X .25" X 4" ANGLE

BOLTS:	#	SIZE (ALL 20/IN) DIAM X LENGTH	DESCRIPTION OF PLACEMENT
	16	1/4" X	CONNECT T BEAM TO I BEAM
	16	3/8" X 1 1/4"	CONNECT I BEAM TO HANGING PLATE

DETERMINATION OF BOLT SIZE:

TOTAL WEIGHT SUPPORTED: 1600# (ARC, MAN, INSTRUMENTS, BEAMS)

ASSUME: WEIGHT IS EVENLY DISTRIBUTED OVER 4 BOLTS

THEREFORE EACH BOLT MUST SUPPORT 400#.

FOR 1/4" BOLTS: $AREA = \frac{\pi(1/4")^2}{4} = .049\ IN^2$

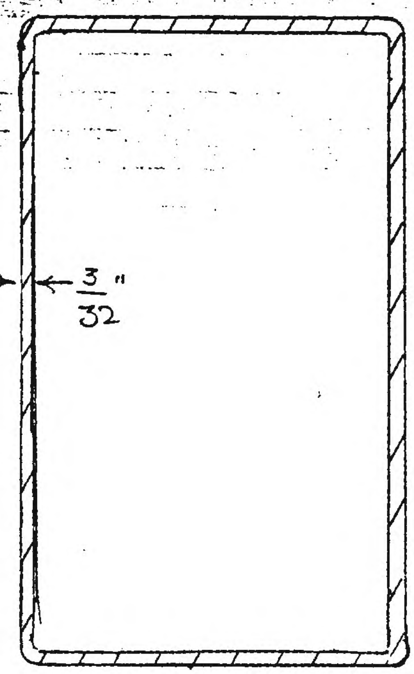
$\sigma = F/A = \frac{400\#}{.049\ IN^2} = 8150$

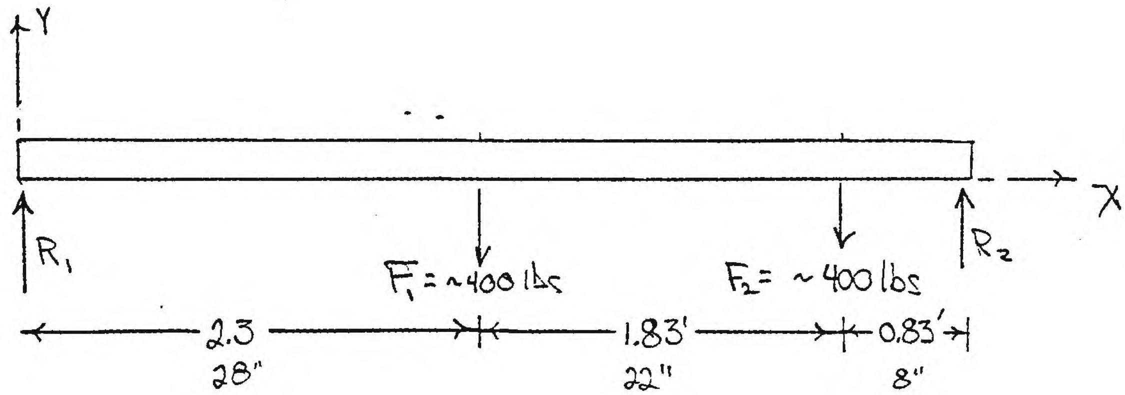
IF USING LOW CARBON STEEL (ASTM A307) (IE. WORST CASE)

$YS = 36\ KSI$ (MECH. ENG DESIGN p 380)

GIVING A $S.F. = \frac{36\ KSI}{8150\ PSI} = 4.41$

CROSS BEAM CALCS.





$$\sum F_y = R_1 + R_2 - 2F = 0 \qquad R_1 + R_2 = 2F$$

$$\sum F_x = 0$$

$$\sum M_o = F_1 x_1 + F_2 x_2 - R_2 L$$

$R_1 + R_2 = 2F = 800\ lbs$

$\therefore F_1 x_1 + F_2 x_2 = R_2 L$

$$\frac{400\,lbs\,(28'' + 50'')}{58''} = R_2 = 537.9\ lbs = \underline{\underline{538\ lbs}}$$

$\therefore R_2 = \underline{\underline{538\ lbs}}$ + $R_1 = \underline{\underline{262\ lbs}}$

$M_{MAX} = 400\ lbs\,(28'') + 400\ lbs\,(50'') = \underline{\underline{31\,200\ in\,lb}}$

$I_{BEAM} = I_{OUTSIDE} - I_{INSIDE}$

$I_{OUTSIDE} = \frac{1}{12} bd^3 = \frac{1}{12}(2'')(3'')^3 = 4.5\ in^4$

$I_{IN} = \frac{1}{12}\left[2 - 2\left(\frac{3''}{32}\right)\right]\left[3 - 2\left(\frac{3}{32}\right)\right]^3 = 3.36\ in^4$

$I_{BEAM} = \underline{\underline{1.14\ in^4}}$

$$\sigma_B = \frac{My}{I} = \frac{(31\,200\ in\,lb)(1'')}{1.14\ in^4} = \underline{\underline{27\,374\ PSI}}$$

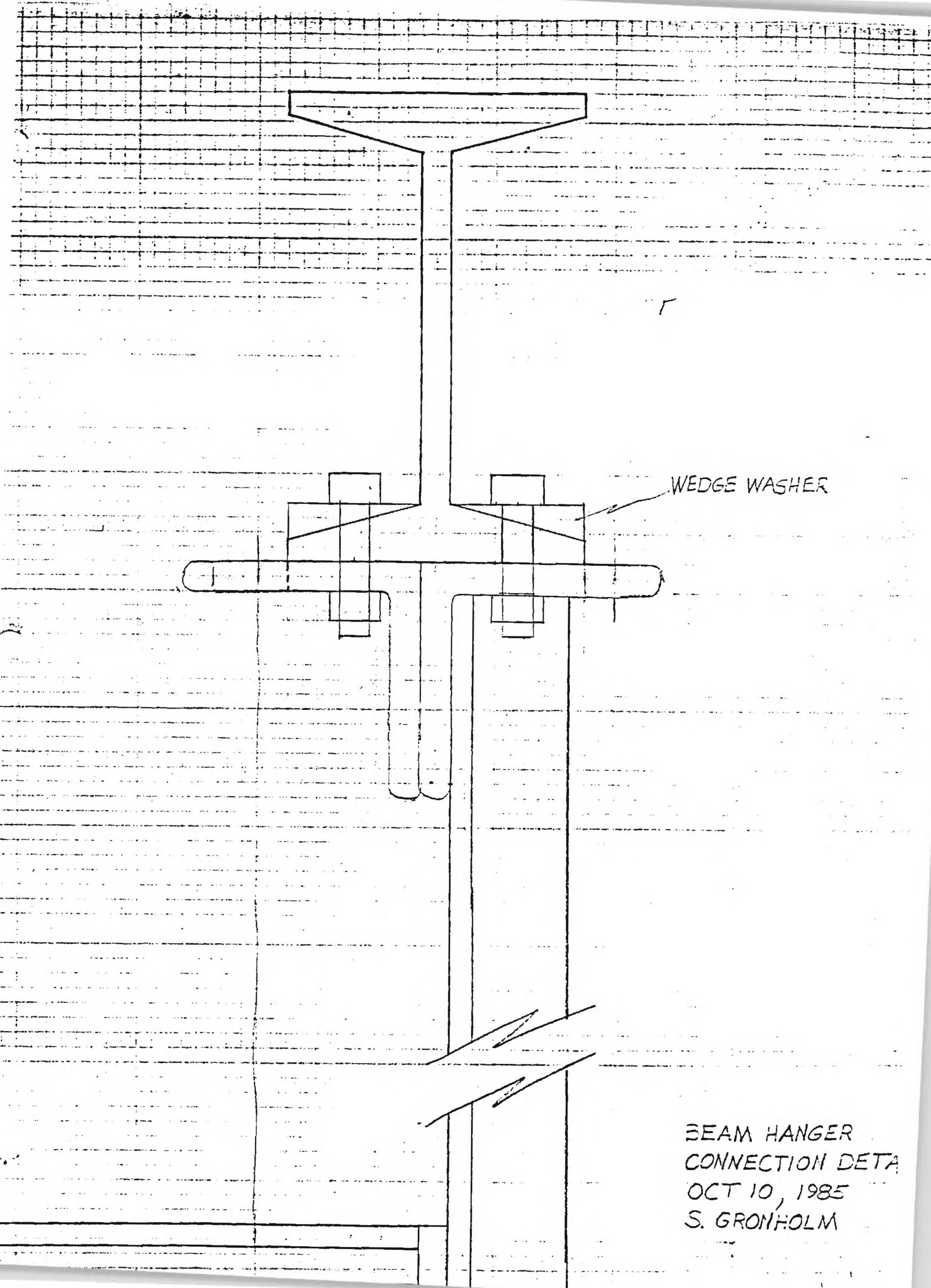
ASSUMING $YS = 36\ KSI$

$\underline{\underline{SF = 1.3}}$

w/ 3" I-Beam

$$\sigma_B = \frac{(31200\ in\,lb)(1.5'')}{2.5\ in^4} = \underline{\underline{18\,720\ PSI}}$$

$$S.F. = \frac{36\ KSI}{18.72\ KSI} = \underline{\underline{1.9}}$$



BEAM HANGER
CONNECTION DETA
OCT 10, 1985
S. GRONHOLM

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF ELECTRICAL ENGINEERING
ATLANTA, GEORGIA 30332

ELEPHONE: (404) 894-2902

December 6, 1985

Dr. Gary Kekelis
Code 4130
Naval Coastal Systems Center
Panama City, FL 32407-5000

SUBJECT: Monthly Status Report
Project Director - D. T. Paris
Contract No. N61331-85-D-0025
"NCSC Omnibus R&D Program"
Period Covered - November 1, 1985 - November 30, 1985

Dear Dr. Kekelis:

The subject report is forwarded in conformance with the contract specifications. A monthly report is included for delivery order #0007 for the period 11/1/85 - 11/30/85.

Should you have any questions or comments regarding this report, please contact Mrs. Cindy Meyer at (404) 894-2961.

Sincerely,

Demetrius T. Paris
Professor and Director

DTP/pm

Addressee: 2 copies
cc: Tom Bryant, ONR
OCA (2)

Monthly Progress/Status Report

NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N61331-85-D-0025

Period Covered: 1 November to 30 November 1985

Order Number: 0007 Title: Unmanned Hyperbaric Breathing Apparatus Testing and Engineering

Task Leader: R. D. Vann

Institution: Duke University Medical Center

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST MONTH

Preparation of the Unmanned Breathing Apparatus Test System (UBATS) for the required testing was continued this month. The CO2 scrubber canister and manekin test rack designs were completed. Materials for the fabrication of the test canisters were ordered while research into finding a membrane/filter material continues. The UBATS arc was installed in Golf chamber, the water holding tank was mounted, and the plumbing of the water conditioning system was finished. The pressure transducer calibration system was installed. All wiring of instrumentation for work of breathing (WOB) testing was completed. The amplifier for the digital scale and the computer software were modified for the required testing. Copies of the data aquisition program and sample output are enclosed.

B. WORK SCHEDULE STATUS

On schedule.

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT MONTH

Work to be done before UBATS Spec. Testing:

	Job:	Man hours required:
1.	Finish mounting arc.	2
2.	Install breathing loop plumbing.	20
3.	Install air supply off "Excursion Line" for breathing supply and pnuematics.	4
4.	Machine and install:	
	4.a. Collins valve fitting.	8
	4.b. Respiratory pump exit fitting.	8

<u>Work to be done before WOB testing begins:</u>

1.	Complete manekin and install connection inside arc.	10
2.	Install nitrogen purge system.	8
3.	Complete water conditioning system.	8
4.	Design test plan.	12
5.	Complete CO2 canister fabrication.	20
6.	UBATS Spec. Testing for subsystem components involved in WOB tests.	12

<u>Work to be done before CO2 canister testing begins:</u>

1.	* Install CO2 system plumbing.	8
2.	* Install CO2 analyzer calibration system.	8
3.	Mount computer terminal.	8
4.	Mount X-Y recorder.	8
5.	Install and test "work-rest cycle" electronics.	24
6.	Change chiller anti-freeze.	2
7.	Add glycol to arc water conditioning system.	
8.	Complete UBATS Spec. Testing.	12
9.	Test on arc water conditioning system.	4

* Must be finished before UBATS Spec. Testing subsystem components

D. PROBLEM AREAS

None.

E. FUNDS EXPENDED

To Date: $49,707

This Month: $13,191

Funds Remaining: $49,213

Percent of Funds Expended: 50%

Percent of Task Completed: Testing has not been started.

```
        AUTHOR: MICHAEL D. FEEZOR, PH.D / MICHAEL NATOLI
        DATE:   NOVEMBER 11, 1985
        FOR:    UNMANNED BREATHING APPARATUS TEST SYSTEM (UBATS)

        TO COMPILE:     FORTRA NCSC/CODE:FIS
        TO LINK:        LINK NCSC,AD,CKSTRT,SYSLIB,FORLIB


LOGICAL*1 INSTR(81)       ! INPUT STRING
COMMON INSTR

LOGICAL*1 BELL
LOGICAL*1 TIME(20)        ! TIME OF DAY
LOGICAL*1 DATES(20)       ! DATE

REAL FULL(2,11)           ! LOW AND HIGH FULL SCALE VALUES
REAL CALVAL(2,11)         ! LOW AND HIGH CAL. SCALE VALUES
REAL GAIN(11)             ! NUMERIC GAIN VALUES
REAL G(11)                ! TEMPORARY  DATA VALUES
REAL OUTARR(5,500)        ! DEBUG DATA ARRAY
REAL VALUE                ! CALIBRATION VARIABLE
REAL SINT                 ! SAMPLING INTERVAL (SECONDS)
REAL CO2WT                ! AMOUNT OF CO2 USED IN A TEST (WT)
REAL DUR                  ! RUNTIME (MINUTES)
REAL MPMAX                ! MAXIMUM MOUTHPIECE PRESSURE
REAL MTMAX                ! TIME OF MAXIMUM MOUTHPIECE PRESSURE

INTEGER*4 JTIME           ! SYSTEM TIME
INTEGER TICK              ! SAMPLING INTERVAL IN 100'S SECOND
INTEGER RUNTIM            ! TIME TO RUN IN CLOCK TICKS
INTEGER CHAN              ! VARIABLE FOR CALIBRATION
INTEGER SCHMIT            ! DUMMY ARGUMENT
INTEGER IADCAL(2,11)      ! HOLDS HIGH AND LOW CALIBRATION VALUES
INTEGER DIGCSR            ! DIGITAL OUTPUT MODULE ADDRESS
INTEGER OUT0              ! OUTPUT A ZERO
INTEGER OUT1              ! OUTPUT A ONE

DATA BELL /7/
DATA DIGCSR /"171262/
DATA OUT1  /0/
DATA OUT0 /2/


ISIZE = 500               ! DEBUG ARRAY SIZE (MAX = 1000)


TYPE 10
FORMAT(//' UNMANNED BREATHING APPARATUS TEST SYSTEM SOFTWARE')


CALIBRATION ROUTINE


OPEN THE CALIBRATION FACTOR FILE

CALL ASSIGN(11,'SY:UBA.CAL',10,'OLD')

READ THE CAL VALUES
```

```
DO 20 I=1,9
        READ(11,1020)IADCAL(1,I)
        READ(11,1000)CALVAL(1,I)
CONTINUE
DO 25 I=1,9
        READ(11,1020)IADCAL(2,I)
        READ(11,1000)CALVAL(2,I)
CONTINUE
CALL CLOSE(11)

TYPE 22
FORMAT(//' CALIBRATION ROUTINE')

CALL DISCAL(IADCAL,CALVAL)      ! DISPLAY THE CAL FACTORS

TYPE 30
FORMAT(//' RE-CALIBRATE ANY INSTRUMENT?--(Y/N)? ',$)

CALL GETSTR(5,INSTR,80)
I= INDEX(INSTR,'Y')
IF (I .EQ. 0) GO TO 130 ! APPARENTLY NOT

DISPLAY THE CALIBRATION MENU

TYPE 40
FORMAT(///' SELECT INSTRUMENT TO BE CALIBRATED')

CALL PUTSTR(5,'     1.  CANISTER TEMP 1')
CALL PUTSTR(5,'     2.  CANISTER TEMP 2')
CALL PUTSTR(5,'     3.  CANISTER TEMP 3')
CALL PUTSTR(5,'     4.  LVDT')
CALL PUTSTR(5,'     5.  DIGITAL SCALE')
CALL PUTSTR(5,'     6.  MASS FLOW METER')
CALL PUTSTR(5,'     7.  MOUTHPIECE PRESSURE TRANSDUCER')
CALL PUTSTR(5,'     8.  CANNISTER PRESSURE TRANSDUCER')
CALL PUTSTR(5,'     9.  CO2 ANALYZER')
CALL PUTSTR(5,'     10. TO START DATA ACQUISTION')

GET THE CHANNEL NUMBER

READ(5,1020)CHAN

IF (CHAN .EQ. 1) GO TO 100
IF (CHAN .EQ. 2) GO TO 100
IF (CHAN .EQ. 3) GO TO 100
IF (CHAN .EQ. 4) GO TO 100
IF (CHAN .EQ. 5) GO TO 100
IF (CHAN .EQ. 6) GO TO 100
IF (CHAN .EQ. 7) GO TO 100
IF (CHAN .EQ. 8) GO TO 100
IF (CHAN .EQ. 9) GO TO 100
IF (CHAN .EQ. 10) GO TO 130

WRITE(5,110)BELL        ! RING THE CONSOLE BELL FOR INVALID ENTRY
FORMAT(A2)
CALL PUTSTR(5,' INVALID ENTRY, PLEASE TRY AGAIN')
GO TO 60

ROUTINE TO GET CALIBRATION VALUES

CALL PUTSTR(5,' HIT RETURN TO GET LOW VALUE')
CALL GETSTR(5,INSTR,80) ! WAIT FOR RETURN
CALL AD(N,CHAN-1)       ! TAKE AN A/D CONVERSION
```

```
CALL PUTSTR(5,' ENTER THE LOW VALUE (NNN.NN)')
READ(5,1000)VALUE
IADCAL(1,CHAN)= N
CALVAL(1,CHAN)= VALUE

CALL PUTSTR(5,' HIT RETURN TO GET HIGH VALUE')
CALL GETSTR(5,INSTR,80) ! WAIT FOR RETURN
CALL AD(N,CHAN-1)         ! TAKE AN A/D CONVERSION
CALL PUTSTR(5,' ENTER THE HIGH VALUE (NNN.NN)')
READ(5,1000)VALUE
IADCAL(2,CHAN)= N
CALVAL(2,CHAN)= VALUE

CALL DISCAL (IADCAL,CALVAL)  ! DISPLAY CAL FACTORS


GO TO 26          ! SHOW THE MENU AGAIN


WRITE CALIBRATION VALUES BACK INTO CALIBRATION FILE

CALL ASSIGN(11,'SY:UBA.CAL',10,'NEW')
DO 140 I=1,9
        WRITE(11,1020)IADCAL(1,I)
        WRITE(11,1000)CALVAL(1,I)
CONTINUE
DO 150 I=1,9
        WRITE(11,1020)IADCAL(2,I)
        WRITE(11,1000)CALVAL(2,I)
CONTINUE
CALL CLOSE(11)

CONTINUE

TYPE 200
FORMAT(/' ENTER THE OUTPUT FILENAME   ',$)
CALL GETSTR(5,INSTR,80,IERR)
CALL TRIM(INSTR)
OPEN(UNIT=11,NAME=INSTR,INITIALSIZE=200,TYPE='NEW')
CALL PUTSTR(11,INSTR,' ',IERR)

TYPE 201
FORMAT(/' ENTER THE TEST NUMBER. (INTEGER) ',$)
READ (5,1020) NTEST
WRITE (11,2010) NTEST
FORMAT (' TEST NUMBER   ',/,I6)

TYPE 202
FORMAT(/' ENTER THE CDS CONFIGURATION. (INTEGER) ',$)
READ (5,1020) NUBA
WRITE (11,2020) NUBA
FORMAT (' CDS CONFIGURATION NUMBER   ',/,I6)

TYPE 203
FORMAT(/' ENTER THE SAMPLE RATE IN SECONDS. (INTEGER) ',$)
READ (5,1020) NMAX
NMAX = NMAX * 50

COPY OPERATING VARIABLES AND CAL. VALUES INTO DATA FILE

CALL DATE(DATES)                  ! GET THE DATE
CALL PUTSTR(11,DATES,' ')         ! WRITE OUT THE DATE
CALL GTIM(JTIME)                  ! GET THE TIME
```

```
      CALL TIMASC(JTIME,TIME)              ! CONVERT TO ASCII
      CALL PUTSTR(11,TIME,' ')             ! WRITE INTO THE FILE

      CALL PUTSTR(11,' LOW CALIBRATION VALUES: ',' ')
      DO 230 I=1,9
              WRITE(11,1030)IADCAL(1,I),CALVAL(1,I)
      CONTINUE

      CALL PUTSTR(11,' HIGH CALIBRATION VALUES: ',' ')
      DO 240 I=1,9
              WRITE(11,1030)IADCAL(2,I),CALVAL(2,I)
      CONTINUE
      WRITE(11,250)
      WRITE(5,250)
      FORMAT(/'    TIME    T1     T2     T3    TVOL   CO2WT
C     CO2FL  MPPR   CANPR  CO2PPM   WOB')

      DETERMINE THE CHANNEL GAINS

      DO 260 I=1,9
              FVAR = FLOAT(IADCAL(2,I) - IADCAL(1,I))
      IF (ABS(FVAR).LT.001)GO TO 9000
              GAIN(I)= (CALVAL(2,I)-CALVAL(1,I))
              GAIN(I)= GAIN(I) / FVAR
      CONTINUE


      RUN FOR THE DURATION
      CALL CKSTRT(SCHMIT,IFLAG,-2)         ! START THE CLOCK AT 10 MS/TICK

      CALL SCCA(IFLG)                      ! SET UP CC INTERCEPT


              INITIALIZE PARAMETERS FOR RESPIRATORY WORK INTEGRATION

      NGT = 0                              ! NUMBER OF INCREASING SAMPLES
      NPK = 5                              ! NEED NGT = NPK TO START INT
      INTFLG = 0                           ! INTEGRATION FLAG
      INTMF = 0                            ! TEMPORARY INTEGRATION FLAG
      VTMP = 0.                            ! PREVIOUS VOLUME COMPARISON
      WORK = 0.
      WRKSUM = 0.
      WRKMAX = 0.                          ! MAXIMUM WORK
      TMAX = 0.                            ! TIME OF MAXIMUM WORK
      MPMAX = 0.                           ! MAXIMUM M.PIECE PRESS
      MTMAX = 0.                           ! TIME OF MAXIMUM M.PIECE PRESS
      CPMAX = 0.                           ! MAXIMUM CANISTER PRESS
      CTMAX = 0.                           ! TIME OF MAXIMUM CANISTER PRESS
      VTMP1 = 0.                           ! VOL. AT START OF INTEGRATION
      PTMP1 = 0.                           ! PRESS. AT START OF INTEGRATION
      CO2WT = 0.                           ! AMOUNT OF CO2 (WT)
      NMAX = 500                           ! SAMPLE EVERY 10 SECONDS
      NSAMP = 0                            ! INIT SAMPLE COUNTER
      NSAMPL = 0                           ! DEBUG PARAMETER
      T= 0.
      G= 0.
      JFLAG = 1                            ! FLAGS WHEN DATA IS WRITTEN
      KFLAG = 0                            ! FLAGS WHEN VOL IS INCREASING
                                             BEFORE THE START OF AN
                                             INTEGRATION


      CONTINUE                             ! BEGIN DATA ACQUISITION
```

```
        N1 = ITTINR()              ! LOOK FOR KEYSTROKE
        IF (N1 .NE. 3) GO TO 290        ! SKIP CODE IF NO CC
        CALL SCCA                  ! DISABLE FURTHER CC IRPS
        GO TO 520                  ! EXIT ON CC

        IF (IFLAG .EQ. 0) GO TO 290     ! WAIT FOR CLOCK

        IFLAG= 0          ! RESET THE FLAG

        GET THE DATA VALUES

        DO 300 J=1,9
                K= J-1
                CALL AD(N,K)     ! GET AN A/D VALUE
                FVAR = FLOAT(N-IADCAL(1,J))    ! CNVRT TO FLOAT
                G(J) = FVAR*GAIN(J)+CALVAL(1,J)
        CONTINUE

        NSAMP = NSAMP + 1
        NSAMPL = NSAMPL + 1                  ! DEBUG PARAMETER


PARAMETERS TO  BE INITIALIZED EACH COMPUTATION PERIOD FOLLOW


        IF (NSAMP .NE. 1) GO TO 301      ! SKIP IF NOT FIRST
                VMAX = G(4)      ! INITIALIZE VOL AND PRES VARS.
                VMIN = G(4)
                VTMP = G(4)      ! TEMP VOLUME STORAGE
                PMAX = G(7)      ! MAX AND MIN MP PRESSURE
                PMIN = G(7)
        CONTINUE

        IF (NSAMP .NE. 2) GO TO 302      ! SKIP IF NOT SECOND
        IF (G(4) .GT. VTMP) KFLAG = 1

CONTINUE

FIND MAXIMUM VOLUME CHANGE AND PEAK MOUTHPIECE PRESSURE

IF (G(4).GT.VMAX) VMAX=G(4)      ! FIND MAXIMUM VOLUME
IF (G(4).LT.VMIN) VMIN=G(4)      ! FIND MINIMUM VOLUME

IF (G(7).GT.PMAX) PMAX=G(7)      ! FIND MAX MOUTHPIECE PRESS.
IF (G(7).LT.PMIN) PMIN=G(7)      ! FIND MIN MOUTHPIECE PRESS.

        BEGIN WORK OF BREATHING (WOB) CALCULATION ROUTINE

IF (G(4) .EQ. VTMP) GO TO 320
IF (G(4) .GT. VTMP) GO TO 310

NGT = NGT -1
IF  (NGT .GE. 0) GO TO 320
        NGT = 0
        INTFLG = 0
        GO TO 320

CONTINUE
NGT = NGT + 1
IF (NGT .LT. NPK) GO TO 320
        NGT = NPK
        INTFLG = 1
```

```
IF (KFLAG .EQ. 1) GO TO 315
        JFLAG = 0
        GO TO 320

        JFLAG = 1

CONTINUE

IF ((INTFLG .EQ. 1) .AND. (INTMF .EQ. 0)) GO TO 330
        INTMF = INTFLG
        WRKSUM = WRKSUM - G(7) * (G(4) - VTMP)  ! UPDATE INTEGRAL
        GO TO 340

        INTMF = INTFLG            ! START INTEGRAL

        KFLAG = 0

ADJUST IF THE INTEGRAL STARTS AT A DIFFERENT POINT

IF (G(4) .LE. VTMP1) GO TO 332
WRKSUM = - G(7) * (G(4)-VTMP) - 1/2 * (G(4)-VTMP1) * (G(7)+PTMP1)
GO TO 335

CONTINUE
IF (G(4) .EQ. VTMP1) GO TO 333
WRKSUM = - G(7) * (G(4)-VTMP) + 1/2 * (G(4)-VTMP1) * (G(7)+PTMP1)
GO TO 335

WRKSUM = - G(7) * (G(4) - VTMP)

CONTINUE
        VTMP1 = G(4)                ! VOL AT START OF INTEGRATION
        PTMP1 = G(7)                ! PRESS AT START OF INTEGRATION

        IF (WRKSUM .GT. WORK) WORK = WRKSUM     ! FIND MAX WORK

        VTMP = G(4)               ! UPDATE TEMP VOLUME



        WRITE OUT RESULTS TO SCREEN AND FILE EVERY NMAX SAMPLES

        DEBUG ARRAY ASSIGNMENTS

IF (NSAMPL .GT. ISIZE) GO TO 508

        OUTARR(1,NSAMPL) = NSAMPL               ! DEBUG
        OUTARR(2,NSAMPL) = G(4)
        OUTARR(3,NSAMPL) = G(7)
        OUTARR(4,NSAMPL) = G(8)
        OUTARR(5,NSAMPL) = WRKSUM

CONTINUE

IF (JFLAG .EQ. 1) WRKSUM = 0.   ! CONSTRAIN INTEGRAL FOR SHORT CYCLE

        IF (NSAMP .LT. NMAX) GO TO 509

        NSAMP = 0                 ! RESET SAMPLE COUNTER

G(4) = (VMAX - VMIN)              ! CALCULATE VOLUME CHANGE
G(7) = PMAX - PMIN                ! ASSIGN P-P MOUTHPIECE PRESS.
G(10) = WORK / 100. / G(4)        ! ASSIGN WORK AND DIV BY TIDAL VOL
```

```
IF (G(10) .LE. WRKMAX) GO TO 350   ! LOOK FOR MAXIMUM WORK
        WRKMAX = G(10)
        TMAX = T                   ! NOTE THE TIME OF MAXIMUM

CONTINUE

IF (G(5) .LE. CO2WT) GOTO 355             ! STORE MAX CO2 WT
        CO2WT = G(5)

CONTINUE

IF (G(7) .LE. MPMAX) GOTO 360             ! FIND MAX M.PIECE PRESS
        MPMAX = G(7)
        MTMAX = T

CONTINUE

IF (G(8) .GE. CPMAX) GOTO 5111            ! FIND MAX CAN. PRESS
        CPMAX= G(8)
        CTMAX = T

CONTINUE

        WRITE(5,1010)T,(G(I2),I2=1,10)
        WRITE(11,1010)T,(G(I2),I2=1,10)

        T= T + SINT       ! INCREMENT ELASPED TIME COUNTER
        T= T + 10.        ! INCREMENT ELASPED TIME COUNTER
        WRKSUM = 0.
        WORK = 0.
        JFLAG = 1
        KFLAG = 0


CONTINUE
GO TO 270                 ! TAKE DATA UNTIL CONTROL C EXIT


CALL IPOKE ("171020,0)  ! STOP THE CLOCK

WRITE(11,1010) (-1.,I2=1,11)     ! TERMINATE NUMERIC DATA C -1

CALL ASSIGN(12,'DK:OUTARR.DAT',13,'NEW')        ! DEBUG OUTPUT FILE

DO 525 J = 1,ISIZE
        WRITE (12,526) (OUTARR(I,J),I=1,5)      !DEBUG
CONTINUE
FORMAT (9F8.2)

CALL CLOSE (12)            ! DEBUG


TYPE 530
FORMAT(//' DO YOU WISH TO ENTER FILE FOOTER DATA?--(Y/N)? ',$)

CALL GETSTR(5,INSTR,80)
I= INDEX(INSTR,'Y')
IF (I .EQ. 0) GO TO 11000          ! BAIL OUT WITHOUT FOOTER DATA
CALL FOOTER(WRKMAX,TMAX,MPMAX,MTMAX,CPMAX,CTMAX,CO2WT)
```

```
      GO TO 11000                ! SKIP ERROR MESSAGES ON NORMAL EXIT

      WRITE (7,10000) I
      FORMAT (' ATTEMPTED ZERODIVIDE AT I = ',I6)

      CALL CLOSE(11)  ! CLOSE THE OUTPUT FILE

      FORMAT(F9.2)
      FORMAT(F7.1,3F6.1,F6.2,F7.2,F6.2,2F7.2,F8.1,F7.3)
      FORMAT(I6)
      FORMAT(I6,F9.2)

      END


      SUBROUTINE FOOTER(WRKMAX,TMAX,MPMAX,MTMAX,CPMAX,CTMAX,CO2WT)


      ACCEPTS FOOTER DATA AND WRITES INTO DATA FILE

      REAL MINPLB,LITPLB
      LOGICAL*1 INSTR (81)
      COMMON INSTR

      INTEGER CO2MSH,CO2MS,CLDR

      REAL MTWT,PRCWT,CO2AWT,TEMPAW,MPTSP,BTSP,CO2FL,CO2IR
      REAL CO2IR2,CO2WT,DEPTH,TRPVOL,MPMAX,MTMAX,FLCODE


      TYPE 4010
      FORMAT (/' ENTER UBA EMPTY WEIGHT (KG). (DECIMAL )',$)
      ACCEPT 1000, MTWT
      MTWT = MTWT * 2.2046
      WRITE (11,3010) MTWT
      FORMAT (/' UBA EMPTY WEIGHT (LBS)-- ',/,F8.2)

      TYPE 4020
      FORMAT (/' ENTER UBA PRE-DIVE CHARGED WEIGHT (KG). (DECIMAL )',$)
      ACCEPT 1000, PRCWT
      PRCWT = PRCWT * 2.2046
      WRITE (11,3020) PRCWT
      FORMAT (' UBA PRE-DIVE CHARGED WEIGHT (LBS)-- ',/,F8.2)

      TYPE 4030
      FORMAT (/' ENTER UBA POST-DIVE CHARGED WEIGHT (KG). (DECIMAL )',$)
      ACCEPT 1000, PDCWT
      PDCWT = PDCWT * 2.2046
      WRITE (11,3030) PDCWT
      FORMAT (' UBA POST-DIVE CHARGED WEIGHT (LBS)-- ',/,F8.2)

      TYPE 4035
      FORMAT (/' ENTER WATER TRAP VOLUME (MLS). (DECIMAL )',$)
      ACCEPT 1000, TRPVOL
      WRITE (11,3035) TRPVOL
      FORMAT (' WATER TRAP VOLUME (MLS)-- ',/,F8.2)

      CO2AWT = PRCWT - MTWT
      WRITE (11,3040) CO2AWT
      FORMAT (' AMOUNT OF CO2 ABSORBANT (LBS)-- ',/,F8.2)

      WRITE (11,3050)
```

```
FORMAT (' CO2 ABSORBANT TYPE-- ')

TYPE 4040
FORMAT (/' ENTER CO2 ABSORBANT TYPE. (80 CHARS. MAX)')
CALL GETSTR (5, INSTR, 80, IERR)
CALL PUTSTR (11, INSTR, ' ', IERR)

TYPE 4050
FORMAT (/' ENTER CO2 ABSORBANT MESH. (INTEGER, INTEGER )', $)
ACCEPT 1025, CO2MSH, CO2MS
WRITE (11,3055) CO2MSH, CO2MS
FORMAT (' CO2 ABSORBANT MESH SIZE-- ', /, I6, ' x 'I6)

TYPE 4060
FORMAT (/' ENTER ARC WATER TEMPERATURE. (DECIMAL )', $)
ACCEPT 1000, TEMPAW
WRITE (11,3060) TEMPAW
FORMAT (' ARC WATER TEMPERATURE (DEG F)-- ', /, F8.2)

TYPE 4070
FORMAT (/' ENTER TEST DEPTH. (DECIMAL )', $)
ACCEPT 1000, DEPTH
WRITE (11,3070) DEPTH
FORMAT (' TEST DEPTH (FSW)-- ', /, F8.2)

TYPE 4080
FORMAT (/' ENTER MOUTHPIECE TEMP SET POINT. (DECIMAL )', $)
ACCEPT 1000, MPTSP
WRITE (11,3080) MPTSP
FORMAT (' MOUTHPIECE TEMP. SET POINT (DEG C)-- ', /, F8.2)

TYPE 4090
FORMAT (/' ENTER CO2 FLOW RATE, WORK CYCLE . (DECIMAL )', $)
ACCEPT 1000, CO2IR
WRITE (11,3090) CO2IR
FORMAT (' CO2 FLOW RATE, WORK CYCLE (LPM)-- ', /, F8.2)

TYPE 4100
FORMAT (/' ENTER CO2 FLOW RATE, REST CYCLE . (DECIMAL )', $)
ACCEPT 1000, CO2IR2
WRITE (11,3100) CO2IR2
FORMAT (' CO2 FLOW RATE, REST CYCLE (LPM)-- ', /, F8.2)

CO2FL = (CO2IR * 0.6) + (CO2IR2 * 0.4)
WRITE (11,3110) CO2FL
FORMAT (' AVERAGE CO2 FLOW RATE (LPM)-- ', /, F8.2)

WRITE (11,3120) CO2WT
FORMAT (' CO2 ABSORBED (LBS)-- ', /, F8.2)

TYPE 4135
FORMAT (/' ENTER 0.5% SEV. BREAKTHROUGH TIME (MIN). (INTEGER )', $)
ACCEPT 2000, IBKMIN

TYPE 41351
FORMAT (/' ENTER 0.5% SEV. BREAKTHROUGH TIME (SEC). (INTEGER )', $)
ACCEPT 2000, IBKSEC
BRKTIM = FLOAT(IBKMIN) + FLOAT(IBKSEC)/60.
WRITE (11,31351) BRKTIM
FORMAT (' 0.5% SEV. BREAKTHROUGH TIME (MIN)-- ', /, F8.2)

TYPE 41352
FORMAT (/' ENTER 1.0% SEV. BREAKTHROUGH TIME (MIN.) INTEGER)', $)
```

```
      ACCEPT 2000, JBKMIN

      TYPE 41353
3     FORMAT (/' ENTER 1.0% SEV. BREAKTHROUGH TIME (SEC.) INTEGER)',$)
      ACCEPT 2000, JBKSEC
      BKTIM = FLOAT(JBKMIN) + FLOAT(JBKSEC)/60.
      WRITE (11,31352) BKTIM
2     FORMAT (' 1.0% SEV. BREAKTHROUGH TIME (MIN)-- ',/,F8.2)

      CO2VOL = CO2WT/.00435            ! .00435 LBS/LITER
      WRITE(11,31353) CO2VOL
3     FORMAT(' CO2 VOLUME ACCORDING TO WT CO2 ABSORBED (L)--',/,F8.2)

      CO2V = CO2FL * BKTIM
      WRITE(11,31354) CO2V
4     FORMAT(' CO2 VOLUME ACCORDING TO CO2 FLOW RATE (L)--',/,F8.2)

      MINPLB = BKTIM/CO2AWT    ! ABSOLUTE EFFICIENCY MIN/LB ABSORB
      WRITE (11,3136) MINPLB
      FORMAT (' EFFICIENCY (MINUTES/LB ABSORBANT)-- ',/,F8.2)

      LITPLB = CO2WT/CO2AWT/.00435     ! LITERS CO2/LB ABSORBANT
      WRITE (11,3137) LITPLB
      FORMAT (' EFFICIENCY (LITERS CO2/LB ABSORBANT)-- ',/,F8.2)

      WRITE (11,3138) WRKMAX
      FORMAT (' MAXIMUM WOB--',/,F8.3)

      WRITE (11,3139) TMAX
      FORMAT (' TIME OF MAXIMUM WOB--',/,F8.2)

      WRITE (11,31391) MPMAX
      FORMAT (' MAXIMUM M.PIECE PRESS--',/,F8.2)

      WRITE (11,31392) MTMAX
      FORMAT (' TIME OF MAXIMUM M.PIECE PRESS--',/,F8.2)

      WRITE (11,31393) CPMAX
      FORMAT (' MAXIMUM CANISTER PRESS--',/,F8.2)

      WRITE (11,31394) CTMAX
      FORMAT (' TIME OF MAXIMUM CANISTER PRESS--',/,F8.2)

      TYPE 4150
      FORMAT (/' ENTER CANISTER CONFIGURATION NUMBER (INTEGER)',$)
      ACCEPT 2000, CLDR
      WRITE (11,4151) CLDR
      FORMAT (' CANISTER CONFIGURATION NO.-- ',/,I6)

      WRITE (11,4157)
      FORMAT (/' FLOW PATTERN-- ')

      TYPE 4160
      FORMAT (/' ENTER FLOW PATTERN. (80 CHARS MAX ).',$)
      CALL GETSTR (5,INSTR,80,IERR)
      CALL PUTSTR (11,INSTR,' ',IERR)

      TYPE 4165
      FORMAT (/' ENTER FLOW PATTERN CODE - AXIAL   = 0.0,',/
     '                               RADIAL, IN-OUT = 1.0,',/
     '                               RADIAL, OUT-IN = 2.0.',/
     '     FLOW PATTERN CODE = ',$)
```

```
      ACCEPT 1001,FLCODE
      WRITE (11,4166)FLCODE
      FORMAT (/' FLOW PATTERN CODE--',/,F8.1)

      TYPE 4300
      FORMAT(/' ENTER COMMENT CODE - SIGNIFICANT COMMENTS = 0.0,',/
C    '                        INSIGNIFICANT COMMENTS = 1.0,',/
C    '        RESULTS EFFECTED GREATLY BY PROCEDURE = 2.0,',/
C    '        RESULTS EFFECTED GREATLY BY PACKING   = 3.0,',/
C    '        RESULTS EFFECTED GREATLY BY OTHER     = 4.0,',/
C    '        COMMENT CODE = ',$)

      ACCEPT 1001,COCODE
      WRITE(11,4400)COCODE
      FORMAT(/' COMMENT CODE--',/,F8.1)

      WRITE (11,4170)
      FORMAT (//' COMMENTS')

      TYPE 4180
      FORMAT (/' ENTER COMMENTS (80 CHARS. MAX). ')
      CALL GETSTR (5,INSTR,80,IERR)
      CALL PUTSTR (11,INSTR,' ',IERR)

      TYPE 4190
      FORMAT (/' ENTER COMMENTS (80 CHARS. MAX). ')
      CALL GETSTR (5,INSTR,80,IERR)
      CALL PUTSTR (11,INSTR,' ',IERR)

      TYPE 4200
      FORMAT (/' ENTER COMMENTS (80 CHARS. MAX). ')
      CALL GETSTR (5,INSTR,80,IERR)
      CALL PUTSTR (11,INSTR,' ',IERR)

      RETURN

      FORMAT (F8.2)
      FORMAT(F8.1)
      FORMAT(2I6)
      FORMAT (I6)

      END



      SUBROUTINE DISCAL(IADCAL,CALVAL)

      DISPLAYS THE CURRENT CALIBRATION FACTORS


      INTEGER IADCAL(2,11)
      REAL CALVAL(2,11)


      TYPE 10
      FORMAT (///'                  CURRENT CALIBRATION FACTORS:',//)

      DO 20 I=1,9
              WRITE (5,1000) (IADCAL(J,I),CALVAL(J,I),J=1,2)
      CONTINUE

      RETURN
```

```
FORMAT (I8,F8.2,I8,F8.2)
END
```

DAT
NUMBER
O
CONFIGURATION NUMBER
O
OV-85
7:31
CALIBRATION VALUES:

O	0.00
7	1.00
7	1.00
7	0.00
O	10.00
O	0.00
5	0.00
1	0.00
9	0.00

H CALIBRATION VALUES:

3	2.99
9	56.00
9	67.00
1	3.00
O	0.00
7	2.00
3	80.00
2	80.00
4	0.50

ME	T1	T2	T3	TVOL	CO2WT	CO2FL	MPPR	CANPR	CO2PPM	WOB
.0	-0.4	40.0	66.3	0.00	30.02	0.00	0.08	-0.20	-1.3	0.010
.0	-0.4	40.0	66.3	0.00	30.00	0.00	0.08	-0.20	-1.3	0.005
.0	-0.4	40.0	66.3	0.00	30.00	0.00	0.08	-0.20	-1.3	0.010
.0	-1.0	-1.0	-1.0	-1.00	-1.00	-1.00	-1.00	-1.00	-1.0	-1.000

EMPTY WEIGHT (LBS)--
.09
PRE-DIVE CHARGED WEIGHT (LBS)--
.30
POST-DIVE CHARGED WEIGHT (LBS)--
.40
R TRAP VOLUME (MLS)--
.00
NT OF CO2 ABSORBANT (LBS)--
.20
ABSORBANT TYPE--

ABSORBANT MESH SIZE--
6 x 12
WATER TEMPERATURE (DEG F)--
.00
DEPTH (FSW)--
.00
HPIECE TEMP. SET POINT (DEG C)--
.60
FLOW RATE, WORK CYCLE (LPM)--
00
FLOW RATE, REST CYCLE (LPM)--
90
AGE CO2 FLOW RATE (LPM)--
56
ABSORBED (LBS)--
02

: SEV. BREAKTHROUGH TIME (MIN)--
). 50
: SEV. BREAKTHROUGH TIME (MIN)--
). 50
VOLUME ACCORDING TO WT CO2 ABSORBED (L)--
. 15
VOLUME ACCORDING TO CO2 FLOW RATE (L)--
. 78
CIENCY (MINUTES/LB ABSORBANT)--
2. 39
CIENCY (LITERS CO2/LB ABSORBANT)--
). 34
IMUM WOB--
010
E OF MAXIMUM WOB--
). 00
IMUM M. PIECE PRESS--
). 08
E OF MAXIMUM M. PIECE PRESS--
). 00
IMUM CANISTER PRESS--
). 20
E OF MAXIMUM CANISTER PRESS--
). 00
STER CONFIGURATION NO. --
0

PATTERN--
AL, IN TO OUT

PATTERN CODE--
1. 0

ENT CODE--
1. 0

ENTS
:

Monthly Progress/Status Report

NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N61331-85-D-0025

Period Covered: 1 December to 31 December 1985

Order Number: 0007 Title: Unmanned Hyperbaric Breathing Apparatus Testing and Engineering

Task Leader: R. D. Vann

Institution: Duke University Medical Center

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST MONTH

Preparation of the Unmanned Breathing Apparatus Test System (UBATS) was completed this month. The UBATS arc was mounted and connections to the breathing loop were made. The breathing loop and the humidity control system were installed and tested. These tasks included the fabrication of a manekin test stand and fittings for the installation of the breathing loop between the ventilator and manekin. An air supply system was installed for the air addition to the breathing loop and control of the tidal volume changer on the ventilator. A nitrogen purge system was installed. The water conditioning system was completed. A prototype CO2 scrubber canister with a gortex filter was fabricated for testing. The CO2 injection system and CO2 sample system were installed. The computer terminal was mounted in the test control area and software was tested. UBATS spec. testing for subsystem components involving Work of Breathing testing was completed.

B. WORK SCHEDULE STATUS

On schedule.

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT MONTH

1) Install automatic work/rest cycle controller.

2) Modify software to accommodate the automatic work/rest cycle.

3) Install a more sensitive diaphram in the canister pressure transducer (0.125 psid as opposed to 1.25 psid).

4) Reverse direction of the WOB loop on the X-Y plotter and modify software accordingly.

5) Fabricate and install a mixing box for more accurate measurement of humidity.

6) Modify air addition system.

7) Modify test stand to accommodate prototype scrubber.

8) Write a testing procedure.

9) Develop a test plan.

10) Complete fabrication of CO2 scrubber canisters.

11) Do preliminary "empty canister" tests.

12) Testing.

13) Data analysis software modifications.

D. PROBLEM AREAS

None.

E. FUNDS EXPENDED

To Date: $62,480

This Month: $12,773

Funds Remaining: $36,440

Percent of Funds Expended: 63%

Percent of Task Completed: Testing has not been started.

Monthly Progress/Status Report

NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N61331-85-D-0025

Period Covered: 1 January to 31 January 1986

Order Number: 0007 Title: Unmanned Hyperbaric Breathing Apparatus Testing and Engineering

Task Leader: R. D. Vann

Institution: Duke University Medical Center

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST MONTH

Subsystem testing and subsequent modification of the Unmanned Breathing Apparatus Test System was completed this month. Canister fabrication was also completed. Preliminary testing was initiated. The automatic work/rest cycle controller and the appropriate software modifications were installed in the system. A more sensitive canister pressure transducer diaphram was installed. Modifications were made in WOB (Work of Breathing) instrumentation and software. A mixing box was installed in the breathing loop to obtain more accurate humidity control. An air addition system was installed. The test stand was modified. Enclosed are copies of the test plan and the test procedure.

B. WORK SCHEDULE STATUS

On schedule.

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT MONTH

1) WOB and CO2 duration testing.

2) Data analysis software modification.

D. PROBLEM AREAS

None.

E. FUNDS EXPENDED

To Date: $74,632

This Month: $12,152

Funds Remaining: $24,188

Percent of Funds Expended: 75%

Percent of Task Completed: System preparation complete.
Preliminary testing complete.
Testing has not been started.

UBATS TEST PROCEDURE
<u>NCSC</u> <u>Closed-Circuit</u> <u>UBA</u>

I. PRETEST PROCEDURE

A. START UP PROCEDURE

1. Air on? (outside bank, pilot air, inside bank)
2. Nitrogen on? (put up Golf orange line)
3. Set chiller temp.
4. Set valves in water system for recirculation through the holding tank (Tank Fill open, Tank Drain open, Pump Supply open, Bypass open, Arc Fill closed, Arc Recirc. closed, and Arc Drain closed.
5. Turn on water system pump. Check for circulation.
6. Obtain desired water temp.
7. Power up instrumentation. (Turn on outlet strip)
8. Turn computer on.
   - -screen will show
     Start?
   - -type:
     DYO(return)
   - -screen:
     RT-11SJ V04.00A
     Enter today's date:
   - -type:
     (day-month abb-year)(return)
   - -screen:
     Enter current time:
   - -type:
     (military time 14:30)(return)
   - -screen:
     .
     .
   - -Put data disc in right drive (DY1)
   - -type:
     DIR
   - -screen:
     Files stored on disc, number of free blocks. (Make sure there is enough storage space on the disc, 450 free blocks. If not, delete oldest file)
       - -type: del filename.dat
       - -screen: are you sure?
       - -type: (y or n)
   - -type:
     R NCSC1(return)
9. Turn on temperature indicators. Check red line.
10. Turn on blowers.
11. Set chamber temperature controller on cool.
12. Open excursion line to chamber and check regulator inside for 60 psi setting.

I. PRETEST PROCEDURE (cont.)

13. Set N2 at 200 psi on the Golf orange bib line.
14. Set all timers to 00000.
15. Close mouthpiece drain, bubbler drain, mixing box drain, and fill the manometer with water.
16. Calibrate LVDT (see LVDT calibration procedure)
17. Turn on ventilator (3.0 l. at 15 BPM).
18. Go through one cycle of tidal volume changes -lubricate if necessary.
19. Set tidal volume on 1.5 liters
    Set breathing frequency at 15 BPM.
20. Turn on mouthpiece temperature controller only. Make sure the correct temperature is set according to the following table:

Arc Temp	-2C/29F	4.5C/40F	21C/70F
Breathing Loop Temp	23C/80.0F	28.6C/83.5F	30.4C/97.5F

21. Calibrate canister delta-p (see Canister Pressure Transducer Calibration Procedure)
22. Calibrate mouthpiece pressure (see MP Pressure Transducer Calibration Procedure).
23. Calibrate CO2 analyzer (0.0 - 4800.0).
24. Calibrate mass flow (see Mass Flow Meter Calibration Procedure).
26. Fill bubbler with warm water.
27. Make sure that the CO2 flow is to the bubbler.
28. Pressure test rig to 20 cm H2O. Leak rate must be below 5 cm H2O per minute.
29. Run a test file (xxx.dat) on the computer and check calibration values and test values.
30. Secure the inside hatch, medical lock, check the chamber, and secure the chamber door.

I. PRETEST PROCEDURE (cont.)

B. UBA PREPARATION:

1. Weigh UBA w/o LiOH (empty weight).
2. Charge UBA w/ absorbant. Tamp down the LiOH after each temperature probe is put in place.
3. Weigh UBA (Must be within 50g of CAN charge normal weight).
4. Record charged weight and absorbant weight and convert to units of lbs. Use 2.20462 lbs/kg to convert
5. Secure all fasteners tightly and grease O-rings if needed.
6. Dip test.
7. Make sure breathing bag(s) are free to inflate.
8. Check all mouthpiece valves.
9. Check for damage in sample, pressure, and air add lines.
10. Blow out sample lines.
11. Secure rig on the pulley above the arc.
12. Hook up pressure and sample lines:
    - CO2 sample on inhalation side
    - air add on exhalation side
    - line from canister transducer to inhalation side
    - line from canister solenoid to exhalation side.
13. Put weights on the rig.

II. TEST PROCEDURE

A. WORK OF BREATHING (WOB) TESTING

1. When holding tank water is at set temperature, fill the arc.(put fill hose in bucket, open ARC FILL, close BYPASS, fill bucket, put hose in arc.)
2. When arc is full, open ARC RECIRC and close PUMP SUPPLY.
3. Check water temperature. (should be +/- 2C of the set temp of 4C for WOB tests)
4. Start computer acquisition:
   screen: Recalibrate any instrument (y or n).
   type: n (return)
   screen: Filename?
   type: Filename.dat (return)(filename =6 letters max)
   screen: Test number?(integer)
   type: Eg. 1 (return)
   screen: CDS configuration number(integer)
   type: Eg. 1 (return)
   screen: sample rate?(integer)
   type: Eg. 10 *when a (return) is hit data acquisition starts.
5. Put chart paper on X-Y plotter
   -mark depth, filename, and date at top of paper.
   -fill out UBADAT sheet.
6. Start X-Y plotter
   (line=ON, chart=HOLD, servo=ON, pen=LIFT)
7. Set tidal volume and frequency (see the table in step 14).
8. Look for at least three stable WOB values(+/-.01).
9. Get a loop by shifting pen to RECORD for one cycle
10. Shift back to LIFT.
11. Stop X-Y plotter by shifting servo to STANDBY.
12. Mark loop as to number (test number, loop number) and computer time.
13. Start X-Y plotter.
14. Repeat steps 5-13 except change step 7 for these RMV's:
    1. 22.5 = 15 BPM at 1.5 LPM.
    2. 40.0 = 20 " at 2.0 " .
    3. 62.5 = 25 " at 2.5 " .
    4. 75.0 = 30 " at 2.5 " .
    5. 90.0 = 30 BPM at 3.0 LPM.
15. Turn on N2 (flowmeters should be set at 5.0 l).

II. TEST PROCEDURE (cont.)

16. Compress to 30.5m.
17. To compress:
    a. Breathing frequency should be on lowest speed.
    b. Open breathing loop solenoid.
    c. Open calibration solenoid V8.
    d. MP calibration switch to V5, CAN cal.switch to V7.
    e. Close calibration system supply (ball valve).
    f. Make sure chamber temperature controller is on cool - both blowers on.
    g. Slowly turn in compression rate control to about 10psi (at the surface turn in fast to get a seal then back off to 10 psi.)
    h. Watch depth, press transducers , inside chamber.
    i. When depth is achieved, back off compression rate controller. Wait 2 min. Makeup depth if necessary.
    j. Open air add solenoid.
    k. Open calibration supply valve (ball valve)
    l. Close breathing loop solenoid.
    m. Close calibration solenoid.
    n. Close air add soleniod when breathing bags are sufficiently full.
18. Repeat steps 5-14.
19. Compress to 60m following compression procedure
20. Repeat steps 5-14.
21. Compress to 90m following compression procedure
22. Repeat steps 5-14.
23. Do CO2 test at appropriate depth.
24. Stop Data Acquisition by hitting (ctrl)(c) once.

B. CO2 TESTING

1. Achieve test depth and allow 30 min in water.
2. Check arc water temp should be +/-2C of set temp.
3. Check humidity (check MP and CAN temperatures).
4. Set tidal volume on 2.0 liters.
5. Set breathing frequency at 25 BPM.
6. Turn on CO2 bottle.
7. Start data aquisition if not already running.
8. To start test:
   Put work/rest controller to auto and turn work/rest controller on and hit reset. Start timer. Record start in computer time.
9. Make sure breathing bags fill sufficiently.
   If not, add air through air add solenoid.
10. Do a set of WOB loops at the beginning of each CO2 test.
11. Open CO2 sample line to CO2 analyzer. Set flow to 1.0 liters/min.
12. Record when analyzer reads .5%SEV and 1.0%SEV.
13. Do a set of WOB loops at the end of each CO2 test.

III. POST TEST PROCEDURE

1. To Decompress:
   a. Set breathing frequency to lowest speed.
   b. Open breathing loop solenoid and cal solenoid.
   c. Set MP cal switch to V5 and can cal switch to V7.
   d. Close cal system supply (ball valve)
   e. Change chamber temp control to heat and turn on both hot water valves.
   f. Open bottom chamber exhaust valve.
   g. Slowly turn in decompression rate controller.
   h. Open manual chamber exhaust valves slowly.
2. Turn off heat tapes.
3. Close all valves when chamber hits surface.
4. Back off decompression rate control.
5. Turn off hot water valves.
6. Turn chamber temp control to cool.
7. Turn off N2. CAUTION !! Do not enter the chamber until chamber air has been circulated for 10 min. with a fan.
8. Turn off ventilator pump.
9. Drain arc and set up for next test.
   SAME DAY
   - Open Bypass and close Arc Fill until the water level is below the mouthpiece connection
   - Open Arc Fill and close Bypass.

   NEXT DAY
   -Turn off water pump.
   -Open Arc Drain.
   -Open Pump Supply.
   -Open Bypass.
   -Close Arc Fill.
   -Close Arc Recirc.
10. Disconnect mouthpiece connection.
11. Raise test stand.
12. Drain bubbler, mixing box, mouthpiece.
13. Disconnect pressure and sample lines.
14. Remove canister from test stand and weigh.
15. Dispose of LiOH using a plastic bag outdoors.
16. Clean and dry all parts.
17. Record data in footnotes by answering terminal
    screen: enter footerdata?(y/n)
    type: y (return)
18. Copy data onto hard disc.
19. Get a printout of data and put in notebook.

Split Breathing Bag System
Breathing Resistance (Pc & Pm) and Work of Breathing (WB)
(TESTS WITHOUT LiOH IN CANISTER:)

		Depth (fsw)										
		0			100			200			300	
anister Config.	RMV lpm	Pc (cmH2O)	Pm	WB km/l	Pc (cmH2O)	Pm	WB km/l	Pc (cmH2O)	Pm	WB km/l	Pc (cmH2O)	Pm
(1)	22.5											
75 L/D	40.0											
adial	62.5	T66										
200 ci	75.0											
	90.0											
(2)	22.5											
25 L/D	40.0											
adial	62.5	T33										
200 ci	75.0											
	90.0											
(3)	22.5											
25 L/D	40.0											
xial	62.5	T12										
200 ci	75.0											
	90.0											
(4)	22.5	T3										
ortex	40.0											
n-to-	62.5											
Out	75.0											
	90.0											
(5)	22.5	T2										
ortex	40.0											
Out-	62.5											
o-In	75.0											
	90.0											
(6)	22.5											
ortex	40.0	T1										
	62.5											
xial	75.0											
	90.0											

ents: (1) Pc = Canister pressure drop
(2) Pm = Mouthpiece pressure drop
(3) See representative graphs of Pc, Pm, and WB vs. Depth in accordance with NEDU 3-81.

Split Breathing Bag System
Breathing Resistance (Pc & Pm) and Work of Breathing (WB)

		Depth (fsw)										
		0			100			200			300	
anister Config.	RMV lpm	Pc (cmH2O)	Pm	WB km/l	Pc (cmH2O)	Pm	WB km/l	Pc (cmH2O)	Pm	WB km/l	Pc (cmH2O)	Pm
(1)	22.5										Goto Pg 3	
.75 L/D	40.0	T45										
Radial	62.5										(1)	
200 ci	75.0										40°/300 FSW	
	90.0											
(2)	22.5										Goto Pg 3	
.25 L/D	40.0											
Radial	62.5	T 23									(2)	
200 ci	75.0											
	90.0										40°/300 FSW	
(3)	22.5										Goto Pg 3	
.25 L/D	40.0											
Axial	62.5	T10									(3)	
200 ci	75.0										40°/300 FSW	
	90.0											
(4)	22.5	T4.									Goto Pg 3	
Gortex	40.0											
In-to-	62.5										(4)	
Out	75.0											
	90.0										40°/300 FSW	
(5)	22.5										Goto Pg 3	
Gortex	40.0	T11										
Out-	62.5										(5)	
to-In	75.0											
	90.0										40°/300 FSW	

ments: (1) Pc = Canister pressure drop
(2) Pm = Mouthpiece pressure drop
(3) See representative graphs of Pc, Pm, and WB vs. Depth in accordance with NEDU 3-81.

Split Breathing Bag System
Canister Duration in Minutes

Canister Config.	Test No.	29 °F 100 fsw	29 °F 300 fsw	40 °F 100 fsw	40 °F 300 fsw	70 °F 300 fsw	
(1) 0.75 L/D Radial 200 ci	1.	T57	T53	T49	T45	T41	
	2.	T59	T55	T51	T47	T43	10
	Mean						
(2) 2.25 L/D Radial 200 ci	1.	T29	T25	T48	T33	T37	
	2.	T31	T27	T50	T35	T39	20
	Mean						
(3) 2.25 L/D Axial 200 ci	1.	xxxxxxx	T20	xxxxxxx	T10	T16	
	2.	xxxxxxx	T22	xxxxxxx	T14	T18	26
		xxxxxxx		xxxxxxx			
	Mean	xxxxxxx		xxxxxxx			
(4) Gortex In-to -Out	1.	T28	T24	T6	T4.	T8	
	2.	T30	T26	T7	T5.	T9	36
	Mean						
(5) Gortex Out -to-In	1.	xxxxxxx	T19	T15	T11	xxxxxxx	
	2.	xxxxxxx	T21	T17	T13	xxxxxxx	42
		xxxxxxx				xxxxxxx	
	Mean	xxxxxxx				xxxxxxx	

Comments: (1) Blocks marked "x" will be omitted.
(2) Standard work/rest cycle used

Activity Level	Time (min)	RMV (lpm)	VCO2 (lpm)
Work	6	50.0	2.0
Rest	4	22.5	0.9

(3) See representative graphs for Canister Bed Temperature vs. Time in accordance with NEDU 3-81.

1c

Single Breathing Bag System
Breathing Resistance (Pc & Pm) and Work of Breathing (WB)
(TESTS WITHOUT LiOH IN CANISTER:)

anister Config.	RMV lpm	Depth (fsw) 0 Pc (cmH2O)	Pm (cmH2O)	WB km/l	100 Pc (cmH2O)	Pm (cmH2O)	WB km/l	200 Pc (cmH2O)	Pm (cmH2O)	WB km/l	300 Pc (cmH2O)	Pm (cmH2O)
~~(1)~~ (7)	22.5											
.75 L/D	40.0	T61 →										
Radial	62.5											
200 ci	75.0											
	90.0											
~~(2)~~ (8)	22.5											
.25 L/D	40.0											
Radial	62.5	T54 →										
200 ci	75.0											
	90.0											
~~(3)~~ (9)	22.5											
.25 L/D	40.0	T52 →										
Axial	62.5											
200 ci	75.0											
	90.0											
~~(4)~~ (10)	22.5											
Gortex	40.0											
In-to-	62.5	T32 →										
Out	75.0											
	90.0											
~~(5)~~ (11)	22.5											
Gortex	40.0	T42 →										
Out-	62.5											
o-In	75.0											
	90.0											
~~(6)~~ (12)	22.5	T46 →										
ortex	40.0											
	62.5											
xial	75.0											
	90.0											

ents: (1) Pc = Canister pressure drop
(2) Pm = Mouthpiece pressure drop
(3) See representative graphs of Pc, Pm, and WB vs. Depth in accordance with NEDU 3-81.

Single Breathing Bag System
Breathing Resistance (Pc & Pm) and Work of Breathing (WB)

		Depth (fsw)										
		0			100			200			300	
nister onfig.	RMV lpm	Pc (cmH2O)	Pm	WB km/l	Pc (cmH2O)	Pm	WB km/l	Pc (cmH2O)	Pm	WB km/l	Pc (cmH2O)	Pm
~~(1)~~ (7)	22.5	T63 ✓ →									WOB ONLY	
75 L/D	40.0											
adial	62.5											
00 ci	75.0											
	90.0											
~~(2)~~ (8)	22.5	T60 ✓ →									GOTO PG 6 (8) 40°/300 FSW	
25 L/D	40.0											
adial	62.5											
00 ci	75.0											
	90.0											
~~(3)~~ (9)	22.5	T56 ✓ →									GOTO PG 6 (9) 40°/300 FSW	
25 L/D	40.0											
xial	62.5											
00 ci	75.0											
	90.0											
~~(4)~~ (10)	22.5	T34 ✓ →									GOTO PG 6 (10) 40°/300 FSW	
ortex	40.0											
n-to-	62.5											
Out	75.0											
	90.0											
~~(5)~~ (11)	22.5	T44 ✓ →									WOB ONLY	
ortex	40.0											
Out-	62.5											
o-In	75.0											
	90.0											

ents: (1) Pc = Canister pressure drop
(2) Pm = Mouthpiece pressure drop
(3) See representative graphs of Pc, Pm, and WB vs. Depth in accordance with NEDU 3-81.

Single Breathing Bag System
Canister Duration in Minutes

		Temp (deg F)	
		40	
Canister Config.	Test No.	100 fsw	300 fsw
~~(2)~~ (2)	1.	T64 ✓	T60 ✓
2.25 L/D	2.	T65 ✓	T62 ✓
Radial			
200 ci	Mean		
~~(2)~~ (1)	1.	xxxxxxx	T56 ✓
2.25 L/D	2.	xxxxxxx	
Axial		xxxxxxx	T58 ✓
200 ci	Mean	xxxxxxx	
~~(1)~~ (10)	1.	T38 ✓	T34 ✓
Gortex	2.	T40 ✓	T36 ✓
In-to			
-Out	Mean		

52

Comments: (1) Standard work/rest cycle used.
(2) See representative graphs for Canister Bed Temperature vs. Time in accordance with NEDU 3-81.

52 CAN DUR
12 NC LiOH
2 WO2 ONLY w/
66 TESTS

Monthly Progress/Status Report

NAVAL COASTAL SYSTEMS CENTER
OMNIBUS R&D PROGRAM
CONTRACT NO. N61331-85-D-0025

Period Covered: 1 February to 28 February 1986

Order Number: 0007 Title: Unmanned Hyperbaric Breathing Apparatus Testing and Engineering

Task Leader: R. D. Vann

Institution: Duke University Medical Center

A. SUMMARY STATEMENT OF WORK COMPLETED DURING THE PAST MONTH

Work of Breathing (WOB) and Canister Duration Testing were initiated. The results of the testing for this month are reported in the enclosed configuration data sheets.

B. WORK SCHEDULE STATUS

On schedule.

C. BRIEF STATEMENT OF PLANNED WORK FOR THE NEXT MONTH

Continuation of WOB and Canister Duration testing, results tabulation, data analysis, and final report generation.

D. PROBLEM AREAS

None.

E. FUNDS EXPENDED

To Date: $91,510

This Month: $16,878

Funds Remaining: $7,410

Percent of Funds Expended: 93%

Percent of Task Completed: 45%

All tests as of
3 March, 1986.

Split Breathing Bag System
Canister Duration in Minutes

		Temperature (deg F)				
		29		40		70
Canister Config.	Test No.	100 fsw	300 fsw	100 fsw	300 fsw	300 fsw
(1)	Min.		112	171	103	124
	Eff.		0.21	0.34	0.22	0.27
0.75 L/D						
	Min.			175	104	
Radial	Eff.			0.37	0.22	
200 ci						
In-to-out	Mean					
(2)	Min.				14.3	41.0
	Eff.				0.04	0.11
2.25 L/D						
	Min.				31.0	
Radial	Eff.				0.06	
200 ci						
In-to-out	Mean					
(3)	Min.	xxxxxxx	213.5	xxxxxxx	221.0	225.0
	Eff.		0.56		0.42	0.45
2.25 L/D		xxxxxxx		xxxxxxx		
	Min.				223.0	
Axial	Eff.	xxxxxxx		xxxxxxx	0.37	
200 ci	Mean	xxxxxxx		xxxxxxx		
(4)	Min.	511.2	465.5	492.0	491.0	411.0
Gortex	Eff.	0.48	0.47	0.45	0.40	0.34
Radial						
Insert,	Min.			451.0	412.0	411.0
2.50 L/D	Eff.			0.36	0.34	0.36
In-to-Out						
456 ci	Mean					
(5)	Min.	xxxxxxx	25.5	111.0	33.0	26.0
	Eff.		0.08	0.24	0.07	0.07
2.25 L/D		xxxxxxx				
	Min.					
Radial	Eff.	xxxxxxx				25.0
Out-to-in						0.07
200 ci	Mean	xxxxxxx				

Comments: (1) Min. = Duration in minutes.
(2) Eff. = Effiency of scrubber,
lbs. CO2 absorbed / lbs. of LiOH in canister.

28 February, 1986

CONFIGURATION NO. 1

DESCRIPTION:

SIGNIFICANT CHANGES: Split breathing bag system.
REGULATOR
(FIRST STAGE): None.
(SECOND STAGE): None.
BREATHING BAG(S): Two (2) bags: Three (3) liters each, on inhalation and exhalation sides of scrubber.

MOUTHPIECE: Scott (Koegal valves were used initially but were found to be unsatisfactory for CO2 tests due to leakage.
CANNISTER: SCR-200-0.75-R: (200 cu. in., L/D = 0.75, Radial.
COMMENTS: Standard heads, flow direction in-to-out.

CONFIGURATION NO. 1

RESULTS CONFIG. NO. 1:

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
41	300	38.419	.269553	124	161	3.2276	

CONFIGURATION NO. 1

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
45	0	5.19	0.70	22.5	.005		
		6.17	1.12	40.0	.008		
		8.76	1.95	62.5	.016		
		10.47	0.70	75.0	.020		
		16.88	3.12	90.0	.026		
45	100	11.56	0.31	22.5	.077		
		23.16	0.71	40.0	.150		
		64.75	1.23	62.5	.397		
		88.56	0.73	75.0	.499		
		128.40	0.85	90.0	.668		
45	200	24.67	0.47	22.5	.167		
		51.52	0.87	40.0	.352		
		129.49	1.13	62.5	.857		
		XXXXX	XXXX	75.0	.XXX		
		XXXXX	XXXX	90.0	.XXX		
45	300	29.17	0.27	22.5	.201		
		67.46	0.42	40.0	.463		
		140.85	1.22	62.5	1.062		
		XXXXX	XXXX	75.0	.XXX		
		XXXXX	XXXX	90.0	.XXX		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
45	300	31.589	.22082	103	164	3.2606	

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
45	300	12.78	0.13	22.5	.090		
		13.43	0.13	40.0	.093		
		32.05	0.57	62.5	.224		
		106.45	1.11	75.0	.741		
		134.36	3.07	90.0	.942		

CONFIGURATION NO. 1

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
47	300	10.98	0.08	22.5	.076	N	pre-
		24.12	0.16	40.0	.177		CO2
		67.47	0.33	62.5	.479		WOB
		xxxxx	xxxx	75.0	xxxx		
		xxxxx	xxxx	90.0	xxxx		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
47	300	32.646	.21659	104	183	3.1857	

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
47	300	7.20	0.38	22.5	.042	N	post
		19.48	0.53	40.0	.139		CO2
		69.10	1.94	62.5	.493		WOB
		xxxxx	xxxx	75.0	xxxx		
		xxxxxx	xxxx	90.0	xxxx		
47	200	24.67	0.47	22.5	.167		
		51.52	0.87	40.0	.352		
		129.49	1.13	62.5	.857		
		XXXXX	XXXX	75.0	.XXX		
		XXXXX	XXXX	90.0	.XXX		

28 February, 1986

CONFIGURATION NO. 1

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
49	100	4.75	1.04	22.5	.007	N	pre-
		6.62	3.98	40.0	.013		CO2
		12.87	7.19	62.5	.058		WOB
		9.38	7.70	75.0	.037		
		13.72	9.34	90.0	.065		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
49	100	52.444	.34349	171	226	3.2606	

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
49	100	4.42	1.39	22.5	.005	N	post
		7.55	3.11	40.0	.020		CO2
		20.38	9.38	62.5	.084		WOB
		31.42	6.78	75.0	.123		
		xxxxx	xxxx	90.0	xxxx		
49	200	4.67	2.79	22.5	.009	N	post
		6.49	5.79	40.0	.024		CO2
		16.60	9.38	62.5	.088		WOB
		24.31	9.38	75.0	.214		
		38.88	8.15	90.0	.204		
49	300	5.07	1.46	22.5	.013	N	post
		7.59	3.02	40.0	.040		CO2
		21.76	9.38	62.5	.142		WOB
		32.55	9.38	75.0	.191		
		xxxxx	xxxx	90.0	xxxx		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
49	100	52.444	.34349	171	226	3.2606	

CONFIGURATION NO. 1

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
51	100	7.14	0.42	22.5	.042	N	pre-
		13.11	0.47	40.0	.084		CO2
		29.83	1.32	62.5	.201		WOB
		40.95	2.34	75.0	.266		
		52.72	3.20	90.0	.345		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
51	100	55.548	.36821	175	213	3.1504	

COMMENTS: No post Co2 WOB due to lack of air to TV changer.

CONFIGURATION NO. 1

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
53	300	34.5125	.21262	112	181	3.2452	

COMMENTS: No MPPR or LVDT.

22 February, 1986

CONFIGURATION NO. 2

DESCRIPTION:

SIGNIFICANT CHANGES: L/D ratio; Split breathing bag system.
REGULATOR
(FIRST STAGE): None.
(SECOND STAGE): None.
BREATHING BAG(S): Two (2) bags: Three (3) liters each, on inhalation and exhalation sides of scrubber.

MOUTHPIECE: Scott (Koegal valves were used initially but were found to be unsatisfactory for CO2 tests due to leakage.
CANISTER: SCR-200-2.25-R: (200 cu. in., L/D = 2.25, Radial.)
COMMENTS: Standard heads, flow direction in-to-out.

CONFIGURATION NO. 2

RESULTS CONFIG. NO. 2:

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
23	0	3.88	0.80	22.5	0.010	Y	
		6.19	1.09	40.0	0.008		
		8.42	1.96	62.5	0.015		
		9.35	1.71	75.0	0.017		
		13.31	3.24	90.0	0.023		
23	100	7.53	0.34	22.5	0.049	Y	
		15.42	0.74	40.0	0.105		
		39.09	0.47	62.5	0.260		
		50.86	2.34	75.0	0.325		
		66.89	1.30	90.0	0.461		
23	200	11.90	0.04	22.5	0.084	Y	
		21.37	0.43	40.0	0.156		
		48.80	1.20	62.5	0.343		
		63.29	0.17	75.0	0.442		
		83.93	2.88	90.0	0.598		
23	300	10.48	0.21	22.5	0.072	Y	
		23.67	0.27	40.0	0.175		
		70.17	0.98	62.5	0.531		
		xxxxx	xxxx	75.0	xxxxx		
		xxxxx	xxxx	90.0	xxxxx		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
23	300	4.972	.03695	14.8	xxx	2.977	

COMMENTS: CO2 test aborted probable valve failure at loop 23.19.

CONFIGURATION NO. 2

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
35	300	13.89	0.23	22.5	0.099	Y	Pre CO2 WOB
		27.45	0.21	40.0	0.196		
		75.49	3.17	62.5	0.551		
		xxxxx	xxxx	75.0	xxxxx		
		xxxxx	xxxx	90.0	xxxxx		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
35	300	10.212	.06259	31.0	61.0	3.0357	

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
35	300	12.10	0.44	22.5	0.080	Y	Post CO2 WOB
		27.05	1.35	40.0	0.196		
		70.21	0.98	62.5	0.501		
		xxxxx	xxxx	75.0	xxxxx		
		xxxxx	xxxx	90.0	xxxxx		

CONFIGURATION NO. 2

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
37	300	10.95	0.19	22.5	0.073	Y	Pre CO2
		20.24	0.31	40.0	0.137		WOB
		xxxxx	xxxx	62.5	xxxxx		
		xxxxx	xxxx	75.0	xxxxx		
		xxxxx	xxxx	90.0	xxxxx		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
37	300	16.074	.10585	41.0	75.0	2.5507	

COMMENTS: No post CO2 WOB.
T2 and T3 are switched.

28 February, 1986

CONFIGURATION NO. 3

DESCRIPTION:

SIGNIFICANT CHANGES: Flow pattern; Split breathing bag system.
REGULATOR
(FIRST STAGE): None.
(SECOND STAGE): None.
BREATHING BAG(S): Two (2) bags: Three (3) liters each, on inhalation and exhalation sides of scrubber.

MOUTHPIECE: Scott (Koegal valves were used initially but were found to be unsatisfactory for CO2 tests due to leakage.
CANNISTER: SCR-200-2.25-A: (200 cu. in., L/D = 2.25, Axial.)
COMMENTS: Standard heads, flow direction axial.

CONFIGURATION NO. 3

RESULTS CONFIG. NO. 3:

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
10	0	5.68	1.40	22.5	0.007	Y	Pre-CO2 WOB
		6.53	1.78	40.0	0.012		
		9.05	2.94	62.5	0.016		
		10.03	4.95	75.0	0.016		
		14.04	4.03	90.0	0.022		
10	100	8.93	1.50	22.5	0.058	Y	
		18.91	2.57	40.0	0.122		
		34.58	5.52	62.5	0.229		
		47.20	5.54	75.0	0.298		
		73.87	9.35	90.0	0.434		
10	200	10.19	1.73	22.5	0.077	Y	
		23.09	3.13	40.0	0.162		
		58.98	9.35	62.5	0.408		
		80.73	9.35	75.0	0.545		
		98.87	9.35	90.0	0.668		
10	300	13.60	1.47	22.5	0.082	Y	
		27.84	3.40	40.0	0.198		
		79.39	9.35	62.5	0.551		
		103.38	6.94	75.0	0.731		
		xxxxxx	xxxx	90.0	xxxxx		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
10	300	62.85	0.4180	221.0	264	3.5164	

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
10	300	10.35	1.93	22.5	0.074	Y	Post CO2 WOB
		28.21	4.80	40.0	0.202		
		97.90	9.35	62.5	0.691		
		xxxxx	xxxx	75.0	xxxxx		
		xxxxx	xxxx	90.0	xxxxx		

COMMENTS: WOB and CO2 tests in different data files.

CONFIGURATION NO. 3

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
12	0	11.21	0.85	22.5	0.043	N	No LiOH
		8.21	0.96	40.0	0.015		
		10.96	1.80	62.5	0.030		
		10.44	1.60	75.0	0.023		
		12.55	2.20	90.0	0.024		
12	100	10.88	0.36	22.5	0.075		
		20.51	0.63	40.0	0.125		
		35.74	1.92	62.5	0.233		
		44.71	2.63	75.0	0.287		
		62.21	0.79	90.0	0.384		
12	200	14.78	0.21	22.5	0.109		
		33.38	1.76	40.0	0.226		
		62.98	2.45	62.5	0.432		
		84.26	0.54	75.0	0.565		
		110.86	7.55	90.0	0.717		
12	300	14.90	0.19	22.5	0.108		
		31.51	0.44	40.0	0.228		
		74.52	1.45	62.5	0.541		
		98.60	0.10	75.0	0.703		
		128.37	3.27	90.0	0.915		

CONFIGURATION NO. 3

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
14	300	63.378	0.3666	223.0	xxx	3.51857	

COMMENTS: T2 andT3 switched. No MPPR or LVDT.

CONFIGURATION NO. 4

DESCRIPTION:

SIGNIFICANT CHANGES: Canister volume, flow pattern, and radial insert material (Gortex). NCSC experimental scrubber No. 3. Split breathing bag system.

REGULATOR
(FIRST STAGE): None.
(SECOND STAGE): None.

BREATHING BAG(S): Two (2) bags: Three (3) liters each, on inhalation and exhalation sides of scrubber.

MOUTHPIECE: Scott (Koegal valves were used initially but were found to be unsatisfactory for CO2 tests due to leakage.

CANNISTER: SCR-456-2.50-R: (456 cu. in., L/D = 2.50, Radial.)

COMMENTS: Standard heads, flow direction in-to-out.

CONFIGURATION NO. 4

RESULTS, CONFIGURATION NO. 4:

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
3	0	6.11	0.13	22.5	0.026	No	
		8.30	0.48	40.0	0.042	No LiOH, base	
		13.20	0.72	62.5	0.073	WOB test, arc	
		15.34	0.82	75.0	0.095	water temp =	
		21.58	1.02	90.0	0.120	40 deg. F.	
3	100	8.14	0.33	22.5	0.052		
		16.19	0.48	40.0	0.113		
		34.90	1.07	62.5	0.247		
		35.91	0.86	75.0	0.265		
		49.39	1.07	90.0	0.364		
3	200	10.65	0.27	22.5	0.071		
		23.44	0.74	40.0	0.174		
		44.13	0.99	62.5	0.334		
		65.75	1.42	75.0	0.478		
		86.96	1.02	90.0	0.640		
3	300	12.39	0.36	22.5	0.089		
		28.79	0.66	40.0	0.212		
		62.67	1.48	62.5	0.465		
		93.93	1.07	75.0	0.683		
		108.58	1.33	90.0	0.816		

CONFIGURATION NO. 4

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
4	0	5.62	0.21	22.5	0.024		WOB/ CAN.
		8.30	0.42	40.0	0.042		DUR. TEST,
		11.78	0.64	62.5	0.072		Arc Temp.
		14.24	0.71	75.0	0.093		= 40 deg. F.
		17.97	0.97	90.0	0.165		
4	100	7.81	0.33	22.5	0.054		
		15.17	0.41	40.0	0.109		
		29.22	1.25	62.5	0.212		
		40.42	1.43	75.0	0.294		
		52.93	1.66	90.0	0.391		
4	200	11.93	0.22	22.5	0.084		
		25.98	0.54	40.0	0.195		
		54.06	1.19	62.5	0.387		
		65.88	1.03	75.0	0.498		
		91.65	1.77	90.0	0.703		
4	300	18.54	0.41	22.5	0.131		
		36.18	0.81	40.0	0.347		
		70.29	1.12	62.5	0.537		
		98.33	1.69	75.0	0.758		
		121.52	1.98	90.0	0.963		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
4	300	61.07	0.397	491	566.5	8.04	40 Deg. F. Arc Temp., WOB / Can. Dur. test. Possibly not enough H20 in bubbler No post can. dur. test.

18 February, 1986

CONFIGURATION NO. 4

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
5	0	4.55	0.96	22.5	0.005		
		6.70	2.15	40.0	0.005		
		7.44	1.49	62.5	0.011		
		8.13	2.35	75.0	0.014		
		11.42	1.11	90.0	0.018		
5	100	7.60	0.08	22.5	0.044		
		12.76	0.46	40.0	0.083		
		27.02	1.96	62.5	0.184		
		36.12	2.66	75.0	0.244		
		47.50	1.31	90.0	0.313		
5	200	8.33	0.09	22.5	0.054		
		18.53	0.41	40.0	0.133		
		46.68	2.00	62.5	0.339		
		65.45	1.37	75.0	0.469		
		81.26	3.15	90.0	0.576		
5	300	9.06	0.32	22.5	0.058		
		19.75	0.18	40.0	0.142		
		56.96	1.10	62.5	0.403		
		78.62	2.09	75.0	0.549		
		93.98	3.24	90.0	0.679		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
5	300	51.43	.342	412.0	n/a	8.01	

COMMENTS: ARC H2O PUMP FAILURE AT +360 MIN INTO CAN DUR TEST
WATER AT 6C - 8C AT FINISH.
NO POST CO2 TEST.

CONFIGURATION NO. 4

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
6	100	16.28	0.68	22.5	0.099	NO	
		31.42	0.62	40.0	0.197		
		63.56	1.54	62.5	0.416	PRE CO2 WOB	
		50.78	1.57	75.0	0.360		
		53.66	0.86	90.0	0.331		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
6	100	11.29	.0757	91.0	186	8.06	

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
6	100	13.84	.52	22.5	0.082	NO	POST CO2 WOB
		22.73	1.04	40.0	0.137		
		37.79	2.04	62.5	0.239		
		39.21	0.18	75.0	0.247		
		XXXXX	XXXX	90.0	XXXXX		NA

CANISTER IN H2O FOR LONG TIME WHILE FIXING TV CHANGER. TOOK ON QUITE A BIT OF H2O WHICH WAS EMPTIED OUT BEFORE TEST.

18 February, 1986

CONFIGURATION NO. 4

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
7	100	7.92	0.51	22.5	0.049	N	PRE CO2
		13.81	0.87	40.0	0.082		WOB

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
7	100	56.11	.36	451	522	8.04	CO2 WOB

WOB NOT TO BE TRUSTED, MP LINE HAS H20(?). POST TEST, EXPIRATION VALVE FOUND DESTROYED. COMP TIME 5120-5580, CO2 ANAL. CALIB.

NO POST CO2 WOB

18 February, 1986

CONFIGURATION NO. 4

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
8	300	8.85	0.38	22.5	0.058		
		17.91	0.17	40.0	0.124		
		62.66	1.15	62.5	0.447		
		85.81	1.77	75.0	0.598		
		112.28	4.24	90.0	0.747		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
8	300	51.10	0.336	411	N/A	8.042	

COMMENTS: NO POST CO2 TEST. MP PRES WAS BAD AT START OF CO2 TEST
CANISTER PRESSURE FULL SCALE THROUGHOUT CO2 TEST.
INHALATION VALVE OF MP LEAKED POST-DIVE.

28 February, 1986

CONFIGURATION NO. 5

DESCRIPTION:

SIGNIFICANT CHANGES: Canister volume, flow pattern
REGULATOR
(FIRST STAGE): None.
(SECOND STAGE): None.
BREATHING BAG(S): Two (2) bags: Three (3) liters each, on inhalation and exhalation sides of scrubber.

MOUTHPIECE: Scott (Koegal valves were used initially but were found to be unsatisfactory for CO2 tests due to leakage.
CANNISTER: SCR-200-2.25-R: (200 cu. in., L/D = 2.25, Radial.)
COMMENTS: Standard heads, flow direction out-to-in.

CONFIGURATION NO. 5

RESULTS CONFIG. NO. 5:

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
2	0	5.24	0.83	22.5	0.005	No	
		6.53	1.33	40.0	0.006	No LiOH, base	
		6.25	1.77	62.5	0.010	WOB Test.	
		5.32	0.74	75.0	0.013	Water Temp.	
		6.58	1.79	90.0	0.013	70 deg. F.	
2	100	5.07	0.15	22.5	0.025		
		8.89	0.52	40.0	0.053		
		23.66	1.10	62.5	0.151		
		31.70	1.82	75.0	0.201		
		39.65	2.07	90.0	0.249		
2	200	7.79	0.24	22.5	0.049		
		19.40	0.69	40.0	0.127		
		43.75	1.17	62.5	0.308		
		61.29	2.12	75.0	0.420		
		68.84	1.76	90.0	0.469		
2	300	8.36	0.16	22.5	0.055		
		20.66	0.41	40.0	0.144		
		54.47	0.64	62.5	0.393		
		83.17	3.30	75.0	0.569		
		XXXXXX	XXXX	90.0	XXXXX		

CONFIGURATION NO. 5

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
15	100	10.20	0.50	22.5	0.067	N	Pre CO2 WOB
		13.81	0.68	40.0	0.101		
		34.29	1.99	62.5	0.261		
		51.74	2.49	75.0	0.390		
		53.40	1.67	90.0	0.396		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
15	100	43.782	.24455	111	xxx	2.535	

COMMENTS: No post CO2 WOB.

CONFIGURATION NO. 5

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
67	300	8.24	0.09	22.5	0.052	Y	x
		15.83	0.15	40.0	0.110		
		54.19	1.38	62.5	0.386		
		72.86	1.07	75.0	0.501		
		85.11	1229	90.0	0.577		

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
67	300	9.6346	.06552	25	64	2.5948	

COMMENTS: No post CO2 WOB.
Water in MPPR lines.

CONFIGURATION NO. 5

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
68	300	12.971	.06682	33	72	2.544	

COMMENTS: Comp. file failed.

14 February, 1986

CONFIGURATION NO. 6

DESCRIPTION:

SIGNIFICANT CHANGES: NCSC experimental scrubber No. 3 without the Gortex radial filter insert. Tested for purposes of determining individual component contributions to WOB. Split breathing bag system.

REGULATOR
(FIRST STAGE): NONE.
(SECOND STAGE): NONE.
BREATHING BAG(S): Two bags, three liters each, placed on inhalation and exhalation heads of the scrubber canister.
MOUTHPIECE: Koegel valve.
CANNISTER: SCR 456-2.5-A.
Standard test heads with "middle" shell as per requirements of Canister No. 3 (Len. = 20.0 in, shell ID = 8.0 in., L/D = 2.5, volume of insert canister = 456 cu. in.)

COMMENTS: This configuration used for WOB tests only.

CONFIGURATION NO. 6

RESULTS CONFIG. NO. 6:

TEST NO.	DEPTH	MTH.P. PRESS.	CAN. PRESS.	RMV	MAX. WOB	TEMP. (Y/N)	COMMENT (Y/N)
1	0	4.83	0.28	22.5	0.017	No	
		12.11	0.28	40.0	0.069		
		15.68	0.37	62.5	0.095	No LiOH, base	
		16.82	0.37	75.0	0.105	WCB Test, Arc.	
		21.90	0.33	90.0	0.126	temp = 40 deg. F.	
1	100	10.56	0.24	22.5	0.068		
		18.12	0.20	40.0	0.125		
		29.53	0.28	62.5	0.218		
		39.70	0.24	75.0	0.296		
		46.97	0.16	90.0	0.348		
1	200	9.26	0.12	22.5	0.067		
		19.34	0.12	40.0	0.141		
		38.44	0.16	62.5	0.284		
		57.86	0.12	75.0	0.421		
		75.17	0.12	90.0	0.559		
1	300	13.18	0.24	22.5	0.092		
		27.55	0.20	40.0	0.203		
		58.90	0.24	62.5	0.437		
		85.03	0.20	75.0	0.623		
				90.0			

UNMANNED DEVELOPMENT TESTING

OF THE

U.S. NAVY CONVENTIONAL DIVING SYSTEM (CDS)

PHASE I

Submitted by:
F. G. Hall Laboratory
Duke University
Durham, North Carolina

Under contract to the
Naval Coastal Systems Center
Panama City, Florida
Georgia Tech. Subcontract No. E-21-J07-S1

Date Submitted:
1 August, 1986

CDS Evaluation and Report Preparation By:

Michael J. Natoli, B.S. BME   Stephen V. Porter, B.S. ME & MS

Report Review By:

R. D. Vann, Ph. D. BME

1 August, 1986
NCSC Phase I CDS Development Project

EXECUTIVE SUMMARY:

The objective of this study was to gather data for the design of a Closed-Circuit Underwater Breathing Apparatus (C/C UBA) with Lithium Hydroxide (LiOH) as the CO_2 scrubbing chemical. Nine C/C UBA configurations were tested to determine the effect of different components and their arrangement on breathing resistance and CO_2 scrubber canister efficiency.

The LiOH used in these tests showed large variations in density and efficiency. Because of these variations, CO_2 canister duration test reproducibility is limited. However, at least three tests for each UBA configuration fall within the NCSC test specification of plus or minus twenty minutes from the median value. CO_2 absorbing efficiency ranges from these tests are below.

Configuration 1:	0.310 - 0.338 gm. CO_2/gm. LiOH
Configuration 2:	0.082 - 0.137 gm. CO_2/gm. LiOH
Configuration 3:	0.432 - 0.464 gm. CO_2/gm. LiOH

CO_2 absorption and water content specification tests were conducted on the LiOH to determine the cause of the variations in density and performance. The tests indicated a water content of 0.8 to 3.2 % and an average CO_2 scrubbing efficiency of 0.490 gm. CO_2/gm. LiOH. The results indicate that the LiOH used in the tests did not meet Military Specification MIL-L-20213E(SH) concerning water content or CO_2 absorption efficiency. Configuration 3 CO_2 scrubber efficiency was close to this test efficiency (split bag UBA, axial flow canister, L/D = 2.25, 200 cu. in.).

Several recommendations are derived from this experience with LiOH.

1) Use only NASA Grade LiOH.
2) LiOH containers should be plastic sealed five gallon pails, not cardboard 200 lb. drums.
3) LiOH must be independently Lot Tested prior to acceptance.

Configuration 3 (with an axial flow canister) had the least WOB and MPP, but the second highest canister delta P.'s. When the same size scrubber was tested with radial instead of axial flow, however, the LiOH efficiency and canister delta P. decreased while WOB and and MPP increased. The cause of theses effects, which were consistent over many tests, is yet to be determined.

Comparisons were made to determine the effects of UBA design parameters (configurations). In terms of CO_2 canister efficiency and breathing resistance, axial flow was found to perform better than radial flow canisters. Two canister length to diameter ratios (L/D) were compared, and the smaller (L/D = 0.75) was found to be superior to the larger (L/D = 2.25) in both breathing resistance performance and canister efficiency. Split bag and single bag systems breathing resistance performance was also tested; Single bag systems were superior with radial flow canisters, but split bag systems were superior with axial flow canisters. No direct corelation between high canister differential pressures and high WOB was found.

TABLE OF CONTENTS:

LIST OF TABLES:

LIST OF FIGURES.

LIST OF FIGURES (con't.):

LIST OF FIGURES (con't.):

INTRODUCTION:

The objective of this study was to gather data on factors affecting the design of a C/C UBA with LiOH as the CO2 scrubbing chemical. LiOH is extremely caustic, therefore UBA design must preclude flood-out and the resulting "caustic cocktail". Nine C/C UBA configurations were tested to determine the effect of different components and their arrangement on breathing resistance and CO2 scrubber canister efficiency.

METHODS:

Nine C/C UBA configurations were fabricated, each with a particular arrangement of components. These UBA configurations (designated Configuration 1 through 9) are described in Tables 1 through 9. The canister heads, breathing bag size, hoses, and mouthpiece were the same for all configurations. The variable components were the number of breathing bags (one or two), canister flow path (axial or radial), direction of radial canister flow (1. flow from the inside of the canister to the outside, designated in-out: 2. Flow from the outside of the canister to the inside, designated out-in), and canister length to diameter ratio (L/D of 0.75 and 2.25). One configuration incorporated an impermeable membrane as a trial feature to prevent caustic cocktail.

Testing began in late January, 1986. In April, 1986 a meeting was held with the NCSC CDS Project Staff to discuss the data and LiOH inconsistancies. Several changes in data gathering methods and procedures were requested, along with additional testing. The changes were implemented and the requested testing was completed. Two blocks of data were generated: Data taken before the April meeting (prior to the changes) is designated Phase I-B. Data gathered after the April meeting is designated Phase I.

The second block of data (Phase I) is emphasized in this report. Phase I data includes breathing resistance tests on Configurations 1, 2, 3, 4, 5, 7, 8 and 9: and CO2 scrubber canister duration tests on Configurations 1, 2, and 3. It is presented in Tables 1 through 20 and Figures 1 through 68. No testing was done on Configuration 6 after the April meeting, consequently there is no Phase I data on it.

Phase I-B data is in tabular form only. It is presented in Appendix E and Table 20. Canister Pressure listed in Phase I-B data is not the same as the Can. Delta P. listed in Phase I data. Breathing resistance data from the two blocks should not be directly compared.

Test conditions were varied to determine their relative effect on UBA performance. Breathing resistance data was taken at 0, 100, 200, and 300 fsw (0, 30.5, 61, and 91.4 msw). Phase I canister duration tests were conducted in 40 deg. F. (4.4 deg. C.) water and at 300 fsw (91.4 msw). Phase I-B canister duration testing varied both water temperature and depth. Tests were conducted in 29, 40, and 70 deg. F. (-1.7, 4.4, and 21.1 deg. C.) water: Water depths were 100 and 300 fsw (30.5 and 91.4 msw).

Figure 65 shows the test set up. Appendix C contains the complete test procedure. The UBATS controls specified test parameters and measures test variables, in accordance with NCSC Unmanned Test Specifications.(1) These are listed below for Phase I data.

Phase I: Controlled Parameters

1. DEPTH
The breathing resistance tests were conducted at 0, 100, 200 and 300 fsw. The canister duration tests were conducted at 300 fsw.

2. AMBIENT ENVIRONMENTAL CONDITIONS
Tests were conducted in a simulated underwater environment at a water temperature 40 deg. F. (4.4 deg. C.).

3. EXHALED BREATHING GAS TEMPERATURE
Simulated exhaled breathing gas temperature was dependent on the ambient water temperature. The temperatures are listed below.

Water Temp. (deg. F./deg. C.)	Gas Temp. (deg. F./deg. C.)
40.0 / 4.4	83.5 / 28.6

4. EXHALED BREATHING GAS HUMIDITY
Simulated exhaled breathing gas humidity was controlled to approximately 90% RH.

5. BREATHING RATE AND VOLUME
Breathing resistance tests were conducted at RMV's simulating light work to heavy work. The breathing rates, tidal volumes, and corresponding RMV's are listed below.

Breathing Rate / Tidal Volume	RMV (L.)
15 BPM / 1.5 L.	22.5
20 BPM / 2.0 L.	40.0
25 BPM / 2.5 L.	62.5
30 BPM / 2.5 L.	75.0
30 BPM / 3.0 L.	90.0

Canister duration tests were conducted at two RMV's simulating rest and work. These were 23.0 RMV (2.0 L. TV / 11.5 BPM) and 50.0 RMV (2.0 L. TV / 25 BPM), respectively.

6. CARBON DIOXIDE (CO_2) PRODUCTION
Two CO_2 production rates were used to simulate rest and work. These were 0.9 LPM and 2.0 LPM, respectively. The CO_2 flow rates and RMV's were alternated simultaneously in a four minute rest period and a six minute work period.

7. BREATHING GAS COMPOSITION AND PRESSURE
The tests were conducted using air as the breathing medium.

8. RESPIRATORY PATTERN
A sinusoidal respiratory pattern was used.

9. PARAMETER CONTROL AND MEASUREMENT
UBA test parameters and UBATS controlled parameters were sampled, stored, and analyzed by digital computer.

Phase I: Measured Variables:

1. MOUTHPIECE PRESSURE
Changes in mouthpiece pressure are an indication of the breathing resistance within a UBA. Peak inspiration to peak expiration mouthpiece differential pressure was measured (Peak MPP). Maximum inspiratory and maximum expiratory pressures were also recorded.

2. TIDAL VOLUME
The tidal volume was measured.

3. WORK OF BREATHING
Work of Breathing (WOB) is a measure of the amount of respiratory work needed to "drive" an UBA. It is a function of the tidal volume and mouthpiece pressure. Simulated lung volume and mouthpiece pressure were plotted on an X-Y recorder (see Figure 57 through 64). The area of the generated loop is the WOB. The WOB was also determined by a digital computer.

4. CARBON DIOXIDE PERCENTAGE
CO2 percentages were measured at the inspiratory side of the CO2 scrubber. Canister "break-through" is at 0.5 % SEV (495 PPM at 300 fsw). At least one 1.0 % SEV (991 PPM at 300 fsw) break-through was done for each configuration.

5. UBA TEMPERATURES
Canister temperatures were measured on each configuration. Three sensors were placed in the canister at different distances from the scrubber inlet. These are subsequently called the "inlet, middle, and outlet" temperature probes. Radial canister temperatures probes were place in the annulus between the radial insert and the scrubber housing. Axial probes were placed in the absorbent bed.

6. PRESSURE DROP ACROSS UBA COMPONENTS
Differential pressure across the scrubber canister was measured during breathing resistance tests.

The FGHL UBATS was used extensively in the development testing and is in described Appendix B. Appendix C lists the UBATS test procedures for C/C UBA.

RESULTS:

Tables 1 through 9 describe each C/C UBA configuration and present Phase I data in tabular form. All data gathered are reported here. However, some parts of tests were aborted due to the high pressures generated. The mouthpiece pressure (MPP) transducer range is 0 to 80 cm. H2O. In most cases, the pressures reported are within this range as the MPP is the total pressure change from inhalation (negative pressure) to exhalation (positive pressure). The Canister Delta P. (Can. Delta P.) transducer range is 0 to 8 cm. H2O.

The configurations were ranked as an aid to interpretation. The UBA configurations were first ranked in order of increasing mouthpiece pressure, WOB, and canister delta P. for all depths and all RMV's. Tests in which portions were aborted were ranked after complete tests. These rankings are presented in Tables 12 through 15.

The rankings for all RMV's from Tables 12 through 15 were then averaged, and then ranked as per the numerical value of the RMV average. These rankings are presented in Table 11.

The RMV Averaged Rankings from Table 11 were then averaged to present a Final Summary of Breathing Resistance Rankings. These rankings are presented in Table 10.

During all of the canister duration tests, breathing resistance data was gathered, too. Mouthpiece pressure data, canister delta P. data, and WOB data from nine selected representative tests were averaged and ranked for Configurations 1, 2, and 3 (three tests each). These averages and rankings are presented in Table 16.

During the April, 1986 meeting with the NCSC project staff a number of special tests were requested. Results from these tests are presented in Table 18.

Scrubber canister inserts are required for Configurations 1 and 2 for radial flow . Although the internal volume of the CO2 scrubber canister's of Configurations 1, 2, and 3 are the same (200 cu. in.), each holds a different amount of LiOH because of the radial flow inserts. Therefore, to compare the performance of these scrubbers, efficiencies must be used. Figures 1 and 2 compare two types of scrubber efficiencies for Configurations 1, 2, and 3. Figure 1 shows the "min. / lb. LiOH" efficiency. This is the number of minutes to the 0.5 % SEV CO2 scrubber canister breakthrough divided by the weight of LiOH in the canister. Figure 2 shows the "Lb. of CO2 absorbed / Lb. of LiOH in the canister" efficiency. Maximum values and minimum values are shown for all three configurations.

Figures 3 through 5 show CO2 % SEV -vs- time for Configurations 1, 2, and 3. The values plotted represent the maximum CO2 % SEV for each ten minute work/rest cycle.

Breathing resistance data is presented in Figures 6 through 56. The data is presented in at least two ways. The UBA configurations are all compared for all depths at each RMV. In these figures which compare all the configurations, some points are obliterated due to computer printer "plot-over." Therefore, data is also presented for all RMV's and each configuration alone.

Figures 6 through 10 show canister delta P.'s -vs- depth for all eight configurations at 22.5, 40.0, 62.5, 75.0, and 90.0 RMV, respectively. Figures 11 through 18 show the same data at all RMV's for each configuration. The canister delta P. is the maximum delta P. for each computer sampling period.

Figures 19 through 23 show mouthpiece pressures -vs- depth for all eight configurations at 22.5, 40.0, 62.5, 75.0, and 90.0 RMV, respectively. Figures 24 through 31 show the same data at all RMV's for each configuration. The mouthpiece pressure is the maximum for each computer sampling period.

Figures 32 through 36 show the WOB -vs- depth for all eight configurations at 22.5, 40.0, 62.5, 75.0, and 90.0 RMV, respectively. Figures 37 through 44 show the same data at all RMV's for each configuration.

Figures 45 through 48 show WOB -vs- RMV for all eight configurations at 0, 100, 200, and 300 fsw, respectively. Figures 49 through 56 show the same data at all depths for each configuration.

Figures 57 through 64 show typical WOB loops for all the configurations. This is Phase I data.

Figures 66 through 68 show CO_2 canister temperatures for Configurations 1 through 3, respectively. Configurations 1 and 2 can be compared directly, but Configuration 3 temperatures were measured differently and therefore can not be compared directly to the other two.

DISCUSSION

The results of this investigation are summarized in Table 10, Table 20, Figure 1 and Figure 2. Table 10 ranks all the configurations by MPP, canister delta P., and WOB. Table 20 compares the design parameters' effect on canister efficiencies and WOB for both Phases of the project, and canister delta P.'s for Phase I. Figures 1 and 2 compare canister efficiencies for Configurations 1, 2, and 3.

Canister Duration:

The LiOH used in these tests showed large variations in density and efficiency. These are discussed in Appendix D. Because of these variations, test reproducibility is limited. However, at least three tests fall within the NCSC test specification of plus or minus twenty minutes from the median value (or average of two median values for Configurations 1 and 2.) These data are presented in Table 17.

LiOH specification tests for CO2 absorption efficiency and water content were conducted because of the variations in density and performance. Samples were exposed to continuous CO2 flow and weighed periodically until no weight change occured. Absorption efficiency was calculated. Other samples were dried to determine water content, and then tested for CO2 absorption efficiency. The results indicate that the water content varied considerably within the same LiOH barrel (0.8 to 3.2 % water content by weight). The efficiency averaged 0.490 gm. CO2/gm. LiOH for the material which was not dried, and 0.509 gm. CO2/gm. LiOH for that which was dried. All efficiency tests were within 0.009 gm. CO2/gm. LiOH of the respective average. These results indicate that the LiOH used in the tests did not meet Military Specification MIL-L-20213E(SH) concerning water content (specification for no more than 0.5 % H20 by weight) or absorption efficiency (specification for not less than 0.7 gm. CO2 absorbed per gm. of LiOH). Several recommendations are derived from this experience with LiOH.

1) Use only NASA Grade LiOH.
2) LiOH containers should be plastic sealed five gallon pails, not cardboard 200 lb. drums.
3) LiOH must be independently batch tested.

Despite the LiOH inconsistancy, it can be seen from Table 17 that Configuration 3 was close to the actual maximum efficiency achieved in the specification tests.

The special tests requested by the NCSC Project Manager are are shown in Table 18. Only one test of each type was conducted, therefore the results are preliminary. Both tests were conducted on Configuration 3, as its previous results were the most consistent. The "Steady Flow Test" (Part A) was done to compare a steady CO2 flow of 1.56 lpm to the varied flow of 0.9 lpm during the rest cycle and 2.0 lpm during the work cycle (as per NCSC Test Specifications.)(1) The steady flow test lasted ten percent longer than the average of the tests within the NCSC Test Specification limit (Table 17). This is , probably due to the lack of a CO2 flow surge. This surge is caused by switching to a different flow meter. The "High Grade LiOH Test" (Part B) was done to compare different grades of LiOH. The "high grade" broke through very rapidly at the 0.5 % SEV but lasted to a nearly normal 1.0 % SEV breakthrough.

Breathing Resistance Test Results:

Configuration 3 had the least breathing resistance, as can be seen in Figures 32 through 36 (and other Figures and Tables). Configuration 3 also had the second highest canister delta P.'s. This oddity was checked by comparing Tables 10 and 16. Table 10 predicts that a comparison between Configurations 1, 2, and 3 would lead to the following results.

Config No.	Predicted MPP Rank	Predicted Can. Delta P. Rank	Predicted WOB Rank
1	2	1	2
2	3	2	3
3	1	3	1

As can be seen in Table 16, these predictions are nearly perfect. The only difference is the ranking for canister delta P. for Configurations 1 and 2. Pressures were very similar for these two configurations, usually within one cm. of water for corresponding tests.

Configuration 3 (with an axial flow canister) had the least WOB and MPP, but the second highest canister delta P.'s. When the same size scrubber was tested with radial instead of axial flow, however, the LiOH efficiency and canister delta P. decreased while WOB and and MPP increased. The cause of theses effects, which were consistent over many tests, is yet to be determined.

Table 20 summarizes the design parameter comparisons for Phase I and also compares them to Phase I-B data. The relative rankings from Phase I-B supports those from Phase I, except in the question of split bag -vs- single bag systems. Both show the superiority of split bag systems for radial flow canisters, but Phase I-B shows it much more clearly.

Limited testing was done to determine the effect canister flow path has on breathing resistance. Comparisons between Table 2, 5 and 10 show that an out to in flow path causes less breathing resistance.

Canister length to diameter ratio (L/D) results show that the smaller L/D had significantly lower breathing resistance. CO2 scrubber canister efficiency was also significantly higher.

Other component configuration results are less clear. Configuration 9 (single bag, axial flow scrubber) had the greatest canister delta P. and comparatively poor breathing resistance. This compared to Configuration 3 would seem to indicate that a single bag configuration is inferior to a split bag for axial flow canisters. However, radial flow introduces an anomalous characteristic which is not understood at this time. Comparisons between Configuration 1 and 7 and between Configurations 2 and 8 indicate that a single bag configuration is superior in terms of breathing resistances for radial flow canisters.

The data for canister pressures indicates that a single bag configuration is inferior to the split bag configuration for both radial and axial flow canisters.

Configuration 2 and 3 data indicates that axial flow canisters are superior to radial flow for split bag UBA. However, comparisons of breathing resistance and canister delta P.'s between Configurations 8 and 9 give mixed results for single bag UBA's.

The rankings in this report are an effort to reduce the large amount of data gathered into understandable results concerning relative UBA performance. In some cases the actual values are very close, which is not indicated by the absolute rank. Data in Tables 1 through 9 should be consulted to determine the actual values of the rankings.

It should be noted that the tests were conducted using air as the "breathing medium." Gas density for the appropriate heliox mixture would be much lower, yielding lower values for breathing resistances and delta P.'s. Also, the mouthpiece and breathing bag flow areas were found to be too small. Phase II testing will correct both of these deficiencies. These small orifices and the high gas density may have introduced artifact into the data.

Phase I-B canister duration tests (Appendix E) indicate that temperature has very little effect on scrubber canister efficiency. Increased pressures cause a slight decrease in efficiency. The variability of this data should temper these conclusions.

Table 19 shows Phase I-B test results for Configurations 4 and 6. Comparison between these two tests show the increased breathing resistance due to the impermeable membrane filter radial flow insert. This insert was fabricated from four commercial filters from Milipore, Inc. The percentage increase in WOB was averaged for all RMV's. The average increase was +32 % at 0 fsw, +14 % at 100 fsw, +15 % at 200 fsw, and + 6 % at 300 fsw. Fabrication of the radial insert was difficult. It would be far easier to isolate the LiOH canister from the diver between two unmodified impermeable filters.

Table 1: Configuration 1: UBA Description and Tabular Data

DESCRIPTION:

CANISTER: SCR-200-0.75-R : (200 cu. in., L/D = 0.75, Radial flow)

BREATHING BAG(S): Split Bag System:
Two (2) bags, one three liter bag on both the inhalation and exhalation sides of scrubber.

MOUTHPIECE: Scott mouthpiece which was the mouthpiece for the Emerson, Mark VI, and Mark XV UBA's.

COMMENTS: Radial flow direction = in-to-out.

Table 1: Configuration 1: UBA Description and Tabular Data (cont.)

CONFIGURATION 1: WOB TEST RESULTS

TEST NO.	DEPTH (FSW)	MPP (CM. H2O)	CAN. DELTA P. (CM. H2O)	RMV (L.)	MAX. WOB (KG. M./L.)	EXHAL. P. (CM. H2O)	INHAL. P. (CM. H2O)
6	0	7.03	0.08	22.5	0.017	0.0	-7.0
		10.40	0.16	40.0	0.025	0.5	-9.9
		13.81	0.28	62.5	0.029	0.5	-13.3
		14.46	0.38	75.0	0.024	0.5	-14.5
		17.55	0.55	90.0	0.028	1.0	-16.6
	100	16.74	0.17	22.5	0.109	4.5	-12.2
		34.13	0.58	40.0	0.215	9.5	-24.6
		60.90	1.46	62.5	0.330	14.0	-46.9
		70.01	1.81	75.0	0.333	14.0	-56.0
		85.36	2.39	90.0	0.380	15.0	-70.4
	200	25.27	0.27	22.5	0.174	8.5	-16.8
		57.37	1.29	40.0	0.386	18.5	-66.9
		104.9	2.44	62.5	0.622	29.0	-75.9
		121.7	2.48	75.0	0.652	29.0	-92.7
		137.3	3.46	90.0	0.734	29.8	-107.5
	300	33.72	0.31	22.5	0.238	12.5	-21.2
		78.70	1.27	40.0	0.536	27.5	-51.2
		134.9	3.21	62.5	0.872	47.5	-87.4
		146.7	3.80	75.0	0.898	48.0	-98.7
		*	*	90.0	*	*	*

* = Test discontinued due to high pressures.

Table 1: Configuration 1: UBA Description and Tabular Data (cont.)

CONFIGURATION 1: CO2 TEST RESULTS

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
6	300	47.9	0.313	154.7	213.0	3.230	Yes: Batch
10	300	47.8	0.310	151.0	*	3.159	No. 3 Prior to Problems.
14	300	35.21	0.234	113.1	*	3.212	Barrel No. 3
15	300	23.43	0.151	82.3	*	3.512	Problems begin.
17	300	55.39	0.358	181.0	*	3.267	Barrel No. 2
22	300	51.65	0.338	163.4	*	3.164	Barrel No. 2.

* = Test not done.

Table 2: Configuration 2: UBA Description and Tabular Data

DESCRIPTION:

CANISTER: SCR-200-2.25-R: (200 cu. in., L/D = 2.25, Radial flow)

BREATHING BAG(S): Split Bag System:
Two (2) bags, one three liter bag on both the inhalation and exhalation sides of scrubber.

MOUTHPIECE: Scott mouthpiece which was the mouthpiece for the Emerson, Mark VI, and Mark XV UBA's.

COMMENTS: Radial flow direction = in-to-out.

Table 2: Configuration 2: UBA Description and Tabular Data (cont.)

CONFIGURATION 2: WOB TEST RESULTS

TEST NO.	DEPTH (FSW)	MPP (CM. H2O)	CAN. DELTA P. (CM. H20)	RMV (L.)	MAX. WOB (KG. M./L.)	EXHAL. P. (CM. H2O)	INHAL. P. (CM. H20)
7	0	7.56	0.15	22.5	0.021	0.5	-7.1
		11.78	0.22	40.0	0.035	1.0	-10.8
		16.54	0.35	62.5	0.041	1.0	-15.5
		12.35	0.22	75.0	0.042	1.0	-11.4
		20.84	0.43	90.0	0.044	1.3	-20.5
	100	18.53	0.24	22.5	0.122	5.5	-13.0
		40.51	0.48	40.0	0.258	13.0	-27.5
		69.96	1.00	62.5	0.394	18.0	-52.0
		78.78	1.60	75.0	0.398	17.0	-61.8
		95.03	1.88	90.0	0.452	18.0	-77.0
	200	28.40	0.45	22.5	0.201	10.0	-18.4
		66.02	0.98	40.0	0.445	23.0	-43.0
		112.9	2.00	62.5	0.688	31.5	-81.4
		129.8	3.55	75.0	0.725	31.0	-98.8
		145.6	3.21	90.0	0.820	35.0	-110.6
	300	35.67	0.78	22.5	0.253	13.5	-22.2
		84.23	2.18	40.0	0.574	31.0	-53.0
		140.3	3.00	62.5	0.910	44.0	-96.3
		151.5	3.19	75.0	0.944	45.0	-106.5
		*	*	90.0	*	*	*

* = Test discontinued due to high pressures.

Table 2: Configuration 2: UBA Description and Tabular Data (cont.)

CONFIGURATION 2: CO2 TEST RESULTS

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
7	300	17.14	0.116	42.9	85.2	2.502	Barrel No. 3
9	300	25.56	0.170	64.8	*	2.535	Prior to
12	300	12.28	0.082	33.0	*	2.687	Problems.
13	300	21.57	0.137	55.2	*	2.560	
16	300	8.70	0.061	22.7	*	2.610	Barrel No. 3
21	300	12.89	0.084	32.2	*	2.498	Problems

* = Test not done.

Table 3: Configuration 3: UBA Description and Tabular Data

DESCRIPTION:

CANISTER: SCR-200-2.25-A: (200 cu. in., L/D = 2.25, Axial flow)

BREATHING BAG(S): Split Bag System:
Two (2) bags, one three liter bag on both the inhalation and exhalation sides of scrubber.

MOUTHPIECE: Scott mouthpiece which was the mouthpiece for the Emerson, Mark VI, and Mark XV UBA's.

COMMENTS: Axial flow .

Table 3: Configuration 3: UBA Description and Tabular Data (cont.)

CONFIGURATION 3: WOB TEST RESULTS

TEST NO.	DEPTH (FSW)	MPP (CM. H2O)	CAN. DELTA P. (CM. H20)	RMV (L.)	MAX. WOB (KG. M./L.)	EXHAL. P. (CM. H2O)	INHAL. P. (CM. H20)
8	0	5.04	0.57	22.5	0.007	0.0	-5.0
		7.03	0.99	40.0	0.009	0.0	-7.0
		9.07	1.64	62.5	0.010	0.0	-9.0
		9.27	1.93	75.0	0.009	0.0	-9.3
		11.38	2.52	90.0	0.012	0.0	-11.4
	100	15.65	1.01	22.5	0.098	4.0	-11.7
		29.67	2.06	40.0	0.170	7.0	-22.7
		47.36	3.75	62.5	0.217	7.5	-39.9
		51.46	4.74	75.0	0.202	7.5	-44.0
		63.58	7.03	90.0	0.218	8.0	-55.6
	200	24.76	1.45	22.5	0.166	8.5	-16.3
		53.70	3.08	40.0	0.334	16.0	-37.7
		89.51	6.05	62.5	0.456	20.5	-69.0
		98.05	7.95	75.0	0.430	18.5	-79.6
		117.6	*	90.0	0.469	18.5	-99.1
	300	32.24	1.93	22.5	0.219	12.0	-20.2
		71.22	4.24	40.0	0.460	23.0	-48.2
		120.0	8.03	62.5	0.659	31.0	-89.0
		130.1	*	75.0	0.680	27.5	-102.6
		144.7	*	90.0	0.653	28.0	-116.7

* = Test discontinued due to high pressures.

Table 3: Configuration 3: UBA Description and Tabular Data (cont.)

CONFIGURATION 3: CO2 TEST RESULTS

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
8	300	66.13	0.432	224.8	262.6	3.400	Barrel 3.
11	300	68.75	0.464	235.4	*	3.424	Prior to Problems.
18	300	69.65	0.449	242.0	*	3.475	Barrel No. 2.
19	300	66.43	0.435	232.0	*	3.492	Barrel No. 2.
20	300	44.03	0.292	175.0	*	3.975	Barrel No. 3 Problems Begin.

Results From Special Tests Suggested by the Project Manager.

STEADY FLOW TEST
RMV = 39.0, CO2 Flow = 1.56 lpm.

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
23	300	74.01	0.485	256.5	*	3.466	Barrel No. 2.

CO2 ABSORBANT = HIGH GRADE LIOH
0.8 g. CO2 / g. LiOH

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
24	300	24.02	0.173	86.0	226.0	3.580	4 X 14 mesh.

* = Test not done.

Table 4: Configuration 4: UBA Description and Tabular Data

DESCRIPTION:

CANISTER: SCR-456-2.50-R: (456 cu. in., L/D = 2.50, Radial flow)

BREATHING BAG(S): Split Bag System:
Two (2) bags, one three liter bag on both the inhalation and exhalation sides of scrubber.

MOUTHPIECE: Scott mouthpiece which was the mouthpiece for the Emerson, Mark VI, and Mark XV UBA's.

COMMENTS: Insert constructed from two Fluorogard filters. The filters used are products of Millipore. The membranes in the filters are 1 micron Gortex.
Radial flow direction = in-to-out.

Table 4: Configuration 4: UBA Description and Tabular Data (cont.)

CONFIGURATION 4: BREATHING RESISTANCE TEST RESULTS

TEST NO.	DEPTH (FSW)	MPP (CM. H2O)	CAN. DELTA P. (CM. H20)	RMV (L.)	MAX. WOB (KG. M./L.)	EXHAL. P. (CM. H2O)	INHAL. P. (CM. H20)
2	0	7.03	0.20	22.5	0.023	0.0	-7.0
		11.02	0.34	40.0	0.037	1.0	-10.0
		16.06	0.59	62.5	0.039	1.0	-15.1
		17.15	0.75	75.0	0.054	1.0	-16.2
		21.59	0.92	90.0	0.026	1.0	-20.6
	100	14.55	0.32	22.5	0.098	3.5	-11.1
		29.92	0.81	40.0	0.198	10.0	-19.9
		56.46	1.67	62.5	0.338	15.5	-41.1
		72.97	2.40	75.0	0.372	16.5	-56.5
		92.60	3.15	90.0	0.425	16.5	-76.1
	200	21.59	0.48	22.5	0.152	7.5	-14.1
		49.92	1.31	40.0	0.342	19.0	-30.9
		96.83	2.63	62.5	0.616	31.5	-65.3
		124.6	2.98	75.0	0.711	32.5	-92.1
		*	*	90.0	*	*	*
	300	28.29	0.60	22.5	0.202	10.5	-17.8
		65.28	1.74	40.0	0.459	27.5	-37.8
		127.6	2.72	62.5	0.841	44.5	-83.1
		148.9	3.64	75.0	0.944	45.0	-103.9
		*	*	90.0	*	*	*

* = Test discontinued due to high pressures.

Table 5: Configuration 5: UBA Description and Tabular Data

DESCRIPTION:

CANISTER: SCR-200-2.25-R: (200 cu. in., L/D = 2.25, Radial flow)

BREATHING BAG(S): Split Bag System:
Two (2) bags, one three liter bag on both the inhalation and exhalation sides of scrubber.

MOUTHPIECE: Scott mouthpiece which was the mouthpiece for the Emerson, Mark VI, and Mark XV UBA's.

COMMENTS: Radial flow direction = out-to-in.

Table 5: Configuration 5: UBA Description and Tabular Data (cont.)

CONFIGURATION 5: BREATHING RESISTANCE TEST RESULTS

TEST NO.	DEPTH (FSW)	MPP (CM. H2O)	CAN. DELTA P. (CM. H20)	RMV (L.)	MAX. WOB (KG. M./L.)	EXHAL. P. (CM. H2O)	INHAL. P. (CM. H20)
1	0	6.87	0.04	22.5	0.023	0.0	-6.9
		11.54	0.09	40.0	0.045	1.0	-10.5
		16.17	0.19	62.5	0.059	1.5	-14.7
		17.71	0.22	75.0	0.054	1.5	-16.2
		1.49	0.31	90.0	0.067	1.5	-20.0
1	100	16.37	0.16	22.5	0.114	4.5	-11.9
		34.54	0.45	40.0	0.236	11.5	-23.0
		62.77	0.88	62.5	0.389	16.5	-46.3
		75.12	1.11	75.0	0.424	18.0	-57.1
		94.59	1.46	90.0	0.508	19.5	-75.1
1	200	23.61	0.28	22.5	0.168	8.0	-15.0
		54.08	0.81	40.0	0.380	20.5	-33.6
		102.4	1.58	62.5	0.668	32.0	-70.4
		121.3	1.93	75.0	0.761	37.5	-83.8
		136.8	2.43	90.0	0.858	40.0	-96.8
1	300	29.54	0.46	22.5	0.218	11.0	-18.5
		72.12	1.18	40.0	0.507	28.5	-43.6
		128.8	2.19	62.5	0.895	47.5	-81.3
		142.9	2.72	75.0	0.971	50.0	-92.9
		*	*	90.0	*	*	*

* = Test discontinued due to high pressures.

Table 6: Configuration 6: UBA Description

DESCRIPTION:

SIGNIFICANT CHANGES: Same as Configuration 4 except impermeable membrane radial flow insert taken out. Tested for purposes of determining individual component contributions to WOB. Split breathing bag system.

BREATHING BAG(S): Two bags, three liters each, placed on inhalation and exhalation heads of the scrubber canister.

MOUTHPIECE: Koegel valve.

CANNISTER: SCR 456-2.5-A.
Standard test heads with "middle" shell as per requirements of Canister Design No. 3 (Len. = 20.0 in, shell ID = 8.0 in., L/D = 2.5, volume of insert canister = 456 cu. in.)

COMMENTS: This configuration used for WOB tests only.
NO PHASE I DATA WAS TAKEN.

Table 7: Configuration 7: UBA Description and Tabular Data

DESCRIPTION:

CANISTER: SCR-200-0.75-R: (200 cu. in., L/D = 0.75, Radial flow.)

BREATHING BAG(S): Single Bag System:
One (1) bag, two three liter bags on the inhalation side of scrubber.

MOUTHPIECE: Scott mouthpiece which was the mouthpiece for the Emerson, Mark VI, and Mark XV UBA's.

COMMENTS: Radial flow direction = in-to-out.

Table 7: Configuration 7: UBA Description and Tabular Data (cont.)

CONFIGURATION 7: BREATHING RESISTANCE TEST RESULTS

TEST NO.	DEPTH (FSW)	MPP (CM. H2O)	CAN. DELTA P. (CM. H2O)	RMV (L.)	MAX. WOB (KG. M./L.)	EXHAL. P. (CM. H2O)	INHAL. P. (CM. H2O)
5	0	6.78	0.19	22.5	0.022	0.0	-6.8
		10.07	0.34	40.0	0.030	0.5	-9.6
		13.20	0.57	62.5	0.035	0.5	-12.7
		13.73	0.66	75.0	0.032	0.5	-13.2
		16.89	0.89	90.0	0.037	0.5	-16.4
	100	15.35	0.44	22.5	0.104	4.0	-11.4
		31.15	1.03	40.0	0.202	9.5	-21.7
		54.38	2.01	62.5	0.315	14.0	-40.4
		62.21	2.51	75.0	0.351	14.0	-48.2
		76.35	3.15	90.0	0.374	14.0	-62.4
	200	21.93	0.70	22.5	0.154	7.5	-14.4
		48.77	1.71	40.0	0.335	17.5	-31.3
		87.19	3.28	62.5	0.553	28.0	-59.2
		103.6	4.16	75.0	0.609	28.5	-75.1
		121.7	5.97	90.0	0.708	32.5	-89.2
	300	28.14	0.97	22.5	0.201	10.5	-17.7
		64.65	2.38	40.0	0.452	26.0	-38.7
		117.7	4.79	62.5	0.774	40.0	-77.7
		126.9	6.26	75.0	0.828	42.5	-84.4
		*	*	90.0	*	*	*

* = Test discontinued due to high pressures.

Table 8: Configuration 8: UBA Description and Tabular Data

DESCRIPTION:

CANISTER: SCR-200-2.25-R: (200 cu. in., L/D = 2.25, Radial flow)

BREATHING BAG(S): Single Bag System:
One (1) bag, two three liter bags on the inhalation side of scrubber.

MOUTHPIECE: Scott mouthpiece which was the mouthpiece for the Emerson, Mark VI, and Mark XV UBA's.

COMMENTS: Radial flow direction = in-to-out.

Table 8: Configuration 8: UBA Description and Tabular Data (cont.)

CONFIGURATION 8: BREATHING RESISTANCE TEST RESULTS

TEST NO.	DEPTH (FSW)	MPP (CM. H2O)	CAN. DELTA P. (CM. H20)	RMV (L.)	MAX. WOB (KG. M./L.)	EXHAL. P. (CM. H2O)	INHAL. P. (CM. H20)
3	0	7.11	0.11	22.5	0.023	0.5	-6.6
		10.81	0.22	40.0	0.034	0.5	-10.3
		14.79	0.42	62.5	0.042	1.0	-13.8
		15.80	0.50	75.0	0.038	1.0	-14.8
		19.38	0.69	90.0	0.041	1.3	-18.1
	100	16.66	0.36	22.5	0.115	4.5	-12.2
		33.80	0.93	40.0	0.223	11.5	-22.3
		61.03	1.95	62.5	0.368	18.0	-43.0
		71.43	2.40	75.0	0.393	18.5	-52.9
		89.91	3.29	90.0	0.467	18.5	-71.4
	200	23.20	0.61	22.5	0.164	7.5	-15.7
		53.51	1.65	40.0	0.373	20.5	-33.0
		100.8	3.44	62.5	0.653	35.0	-65.8
		121.0	4.35	75.0	0.735	37.5	-83.5
		133.7	5.54	90.0	0.834	40.0	-93.7
	300	29.58	0.82	22.5	0.207	11.0	-18.6
		69.56	2.29	40.0	0.468	29.5	-40.1
		129.3	4.78	62.5	0.882	45.0	-84.3
		140.0	5.98	75.0	0.948	47.5	-92.5
		*	*	90.0	*	*	*

* = Test discontinued due to high pressures.

Table 9: Configuration 9: UBA Description and Tabular Data

DESCRIPTION:

CANISTER: SCR-200-2.25-A: (200 cu. in., L/D = 2.25, Axial flow)

BREATHING BAG(S): Single Bag System:
One (1) bag, two three liter bags on the inhalation side of scrubber.

MOUTHPIECE: Scott mouthpiece which was the mouthpiece for the Emerson, Mark VI, and Mark XV UBA's.

COMMENTS: Axial flow.

Table 9: Configuration 9: UBA Description and Tabular Data (cont.)

CONFIGURATION 9: BREATHING RESISTANCE TEST RESULTS

TEST NO.	DEPTH (FSW)	MPP (CM. H2O)	CAN. DELTA P. (CM. H20)	RMV (L.)	MAX. WOB (KG. M./L.)	EXHAL. P. (CM. H2O)	INHAL. P. (CM. H20)
4	0	6.74	1.37	22.5	0.022	0.5	-6.2
		10.36	2.47	40.0	0.029	1.0	-9.4
		13.94	3.99	62.5	0.024	1.0	-12.9
		14.34	4.48	75.0	0.017	1.0	-13.3
		17.43	5.73	90.0	0.019	1.0	-16.4
	100	18.36	3.02	22.5	0.124	6.5	-11.9
		37.58	6.52	40.0	0.227	11.5	-26.1
		60.78	*	62.5	0.303	13.5	-47.3
		69.60	*	75.0	0.282	12.0	-57.5
		85.81	*	90.0	0.311	12.0	-73.8
	200	30.96	4.58	22.5	0.212	13.5	-17.5
		67.45	*	40.0	0.430	24.0	-43.5
		116.7	*	62.5	0.627	32.5	-84.2
		122.0	*	75.0	0.605	30.0	-92.0
		*	*	90.0	*	*	*
	300	39.90	5.38	22.5	0.275	19.0	-20.9
		88.69	*	40.0	0.581	34.0	-54.7
		130.8	*	62.5	0.814	35.0	-95.8
		*	*	75.0	*	*	*
		*	*	90.0	*	*	*

* = Test discontinued due to high pressures.

Table 10: Final Summary of Breathing Resistance Rankings:

Description	Config. No.	MPP Rank	Can. Delta P. Rank	WOB Rank
No. of BB: 2 Flow: Rad,I-O Vol: 200 cu.in. L/D: 0.75	1	5	2	4
No. of BB: 2 Flow: Rad, I-O Vol: 200 cu.in. L/D: 2.25	2	8	3	8
No. of BB: 2 Flow: Axial Vol: 200 cu.in. L/D: 2.25	3	1	7	1
No. of BB: 2 Flow: Rad, I-O Vol: 456 cu.in. L/D: 2.50 NOTE: Impermeable membrane insert.	4	3	4	3
No. of BB: 2 Flow: Rad, O-I Vol: 200 cu.in. L/D: 2.25	5	7	1	7
No. of BB: 1 Flow: Rad, I-O Vol: 200 cu.in. L/D: 0.75	7	2	6	2
No. of BB: 1 Flow: Rad, I-O Vol: 200 cu.in. L/D: 2.25	8	4	5	6
No. of BB: 1 Flow: Axial Vol: 200 cu.in. L/D: 2.25	9	6	8	5

Note:
No. of BB: = Number of breathing bags
Flow: Rad, I-O = Radial flow, In to out
Flow: Rad, O-I = Radial flow, Out to in
Vol: = volume (cubic inches)
L/D: = Length to diameter ratio

Table 11: RMV Averaged Summary of Breathing Resistance Rankings:

Config. No.	Depth (fsw)	MPP Rank	Can. Delta P. Rank	WOB Rank
1	0	4	2	3
No. of BB: 2	100	4	3	8
Flow: Rad, I-O	200	5	2	3
Vol: 200 cu.in.	300	6	3	6
L/D: 0.75				
2	0	6	3	5
No. of BB: 2	100	8	2	8
Flow: Rad, I-O	200	6	3	8
Vol: 200 cu.in.	300	7	4	7
L/D: 2.25				
3	0	1	7	1
No. of BB: 2	100	1	7	1
Flow: Axial	200	1	7	1
Vol: 200 cu.in.	300	4	7	1
L/D: 2.25				
4	0	8	6	6
No. of BB: 2	100	3	4	3
Flow: Rad, I-O	200	2	4	4
Vol: 456 cu.in.	300	2	2	2
L/D: 2.50 (Note: Gortex Canister Insert)				
5	0	7	1	8
No. of BB: 2	100	7	1	7
Flow: Rad, O-I	200	7	1	7
Vol: 200 cu.in.	300	5	1	5
L/D: 2.25				
7	0	2	5	4
No. of BB: 1	100	2	6	2
Flow: R,I-O	200	3	6	2
Vol: 200 cu.in	300	1	6	3
L/D: 0.75				
8	0	5	4	7
No. of BB: 1	100	5	5	6
Flow: Rad, I-O	200	4	5	5
Vol: 200 cu.in.	300	3	5	4
L/D: 2.25				
9	0	3	8	2
No. of BB: 1	100	6	8	5
Flow: Axial	200	8	8	6
Vol: 200 cu.in.	300	8	8	8
L/D: 2.25				

Note:
See notes on bottom of Table 10.

Table 12: Breathing Resistance Ranking at 0 fsw:

Config. No.	RMV (L.)	MPP Rank	Can. Delta P. Rank	WOB Rank
1	22.5	5	2	2
	40.0	4	2	2
	62.5	3	2	3
	75.0	5	3	3
	90.0	4	3	4
2	22.5	8	4	3
	40.0	8	4	6
	62.5	8	3	6
	75.0	2	1	6
	90.0	6	2	7
3	22.5	1	7	1
	40.0	1	7	1
	62.5	1	7	1
	75.0	1	7	1
	90.0	1	7	1
4	22.5	6	6	7
	40.0	6	6	7
	62.5	6	6	5
	75.0	7	6	7
	90.0	8	6	3
5	22.5	4	1	6
	40.0	7	1	8
	62.5	7	1	8
	75.0	8	2	8
	90.0	7	1	8
7	22.5	3	5	5
	40.0	2	5	4
	62.5	2	5	4
	75.0	3	5	4
	90.0	2	5	5
8	22.5	7	3	8
	40.0	5	4	5
	62.5	5	4	7
	75.0	6	4	5
	90.0	5	4	6
9	22.5	2	8	4
	40.0	3	8	3
	62.5	4	8	2
	75.0	4	8	2
	90.0	3	8	2

* Tests canceled due to high pressures.

Table 13: Breathing Resistance Ranking at 100 fsw:

Config. No.	RMV (L.)	MPP Rank	Can. Delta P. Rank	WOB Rank
1	22.5	6	2	4
	40.0	5	3	4
	62.5	5	3	4
	75.0	4	3	3
	90.0	3	3	4
2	22.5	8	3	7
	40.0	8	2	8
	62.5	8	2	8
	75.0	8	2	7
	90.0	8	2	6
3	22.5	3	7	1
	40.0	1	7	1
	62.5	1	7	1
	75.0	1	7	1
	90.0	1	7	1
4	22.5	1	4	1
	40.0	2	4	2
	62.5	3	4	5
	75.0	6	5	5
	90.0	6	5	5
5	22.5	4	1	5
	40.0	6	1	7
	62.5	7	1	7
	75.0	7	1	8
	90.0	7	1	8
7	22.5	2	6	3
	40.0	3	6	3
	62.5	2	6	3
	75.0	2	6	4
	90.0	2	4	3
8	22.5	5	5	6
	40.0	4	5	5
	62.5	6	5	6
	75.0	5	4	5
	90.0	5	6	7
9	22.5	7	8	8
	40.0	7	8	6
	62.5	7	8	2
	75.0	3	*	2
	90.0	4	*	2

* Tests canceled due to high pressures.

Table 14: Breathing Resistance Ranking at 200 fsw:

Config. No.	RMV (L.)	MPP Rank	Can. Delta P. Rank	WOB Rank
1	22.5	7	1	6
	40.0	6	3	6
	62.5	6	3	4
	75.0	*	2	4
	90.0	*	3	3
2	22.5	6	3	7
	40.0	7	2	8
	62.5	7	2	8
	75.0	*	4	6
	90.0	*	2	*
3	22.5	5	7	4
	40.0	4	7	1
	62.5	1	7	1
	75.0	1	7	1
	90.0	1	*	1
4	22.5	1	4	1
	40.0	1	4	3
	62.5	3	4	3
	75.0	*	3	5
	90.0	*	*	*
5	22.5	4	2	5
	40.0	5	1	5
	62.5	5	1	7
	75.0	*	1	8
	90.0	*	1	*
7	22.5	2	6	2
	40.0	2	6	2
	62.5	2	5	2
	75.0	2	5	3
	90.0	*	5	2
8	22.5	3	5	3
	40.0	3	5	4
	62.5	4	6	6
	75.0	*	6	7
	90.0	*	4	*
9	22.5	8	8	8
	40.0	8	*	7
	62.5	8	*	5
	75.0	*	*	2
	90.0	*	*	*

* Tests canceled due to high pressures.

Table 15: Breathing Resistance Ranking at 300 fsw:

Config. No.	RMV (L.)	MPP Rank	Can. Delta P. Rank	WOB Rank
1	22.5	7	1	6
	40.0	6	2	6
	62.5	*	4	*
	75.0	*	4	*
	90.0	*	*	*
2	22.5	6	4	7
	40.0	7	4	7
	62.5	*	3	*
	75.0	*	2	*
	90.0	*	*	*
3	22.5	5	7	5
	40.0	4	7	2
	62.5	2	7	1
	75.0	*	*	1
	90.0	*	*	1
4	22.5	2	3	2
	40.0	2	3	1
	62.5	*	2	*
	75.0	*	3	*
	90.0	*	*	*
5	22.5	3	2	4
	40.0	5	1	5
	62.5	*	1	*
	75.0	*	1	*
	90.0	*	*	*
7	22.5	1	6	1
	40.0	1	6	3
	62.5	1	6	2
	75.0	*	6	*
	90.0	*	*	*
8	22.5	4	5	3
	40.0	3	5	4
	62.5	*	5	*
	75.0	*	5	*
	90.0	*	*	*
9	22.5	8	8	8
	40.0	8	*	*
	62.5	*	*	*
	75.0	*	*	*
	90.0	*	*	*

Table 16: Breathing Resistance Averages and Ranking During Representative Canister Duration Tests:

Config. No.	Ave. MPP (cm. H2O) / Rank	Ave. Can. Delta P. (cm. H2O) / Rank	Ave. WOB (kg. m. / L.) / Rank	Tests No.
1	78.02 / 2	3.73 / 2	0.524 / 2	11,15,22
2	80.22 / 3	1.93 / 1	0.537 / 3	12,16,21
3	73.11 / 1	5.84 / 3	0.503 / 1	11,19,23

TABLE 17: CO2 CANISTER DURATION TESTS WITHIN NCSC TEST SPECS:

CONFIG. NO.	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	
		CONFIGURATION 1: CO2 TEST RESULTS				
1	47.9	0.313	154.7	213.0	3.230	
1	47.8	0.310	151.0	*	3.159	
1	51.65	0.338	163.4	*	3.164	
Averages	49.1	0.320	156.4		3.184	Averages
		CONFIGURATION 2: CO2 TEST RESULTS				
2	17.14	0.116	42.9	85.2	2.502	
2	12.28	0.082	33.0	*	2.687	
2	21.57	0.137	55.2	*	2.560	
2	12.89	0.084	32.2	*	2.498	
Averages	15.97	0.105	40.8		2.562	Averages
		CONFIGURATION 3: CO2 TEST RESULTS				
3	66.13	0.432	224.8	262.6	3.400	
3	68.75	0.464	235.4	*	3.424	
3	69.65	0.449	242.0	*	3.475	
3	66.43	0.435	232.0	*	3.492	
Averages	67.74	0.445	233.6		3.448	Averages

TABLE 18: SPECIAL TESTS REQUESTED BY NCSC PROJECT MANAGER:

PART A :STEADY FLOW TEST
Configuration 3:

RMV = 39.0, CO2 Flow = 1.56 lpm.

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
23	300	74.01	0.485	256.5	*	3.466	Barrel No. 2.

PART B: CO2 ABSORBANT = HIGH GRADE LIOH
0.8 g. CO2 / g. LiOH

TEST NO.	DEPTH (FSW)	MIN./ LB. LiOH	LB.CO2/ LB. LiOH	0.5% B.T. (MIN.)	1.0% B.T. (MIN.)	WT. LiOH (LBS.)	COMMENT (Y/N)
24	300	24.02	0.173	86.0	226.0	3.580	4 X 14 mesh.

TABLE 19: PHASE I-B RESULTS FOR IMPERMEABLE MEMBRANE CANISTER:

RESULTS, CONFIGURATION NO. 4 WITHOUT LiOH IN THE CANISTER::

TEST NO.	DEPTH	MTH.P. PRESS. (CM. H2O)	CAN. PRESS. (CM. H20)	RMV (L.)	MAX. WOB (KG. M./L.)	TEMP. (Y/N) (CM. H2O)	COMMENT (Y/N) (CM. H20)
3	0	6.11	0.13	22.5	0.026	No	
		8.30	0.48	40.0	0.042	No LiOH, base	
		13.20	0.72	62.5	0.073	WOB test, arc	
		15.34	0.82	75.0	0.095	water temp =	
		21.58	1.02	90.0	0.120	40 deg. F.	
3	100	8.14	0.33	22.5	0.052		
		16.19	0.48	40.0	0.113		
		34.90	1.07	62.5	0.247		
		35.91	0.86	75.0	0.265		
		49.39	1.07	90.0	0.364		
3	200	10.65	0.27	22.5	0.071		
		23.44	0.74	40.0	0.174		
		44.13	0.99	62.5	0.334		
		65.75	1.42	75.0	0.478		
		86.96	1.02	90.0	0.640		
3	300	12.39	0.36	22.5	0.089		
		28.79	0.66	40.0	0.212		
		62.67	1.48	62.5	0.465		
		93.93	1.07	75.0	0.683		
		108.58	1.33	90.0	0.816		
3	300	12.39	0.36	22.5	0.089		
		28.79	0.66	40.0	0.212		
		62.67	1.48	62.5	0.465		
		93.93	1.07	75.0	0.683		
		108.58	1.33	90.0	0.816		

TABLE 19: PHASE I-B RESULTS FOR IMPERMEABLE MEMBRANE CANISTER (CON'T):

RESULTS, CONFIGURATION NO. 6:

TEST NO.	DEPTH	MTH.P. PRESS. (CM. H2O)	CAN. PRESS. (CM. H2O)	RMV (L.)	MAX. WOB (KG. M./L.)	TEMP. (Y/N) (CM. H2O)	COMMENT (Y/N) (CM. H2O)
1	0	4.83	0.28	22.5	0.017	No	
		12.11	0.28	40.0	0.069		
		15.68	0.37	62.5	0.095	No LiOH, base	
		16.82	0.37	75.0	0.105	WOB Test, Arc.	
		21.90	0.33	90.0	0.126	temp = 40 deg. F.	
1	100	10.56	0.24	22.5	0.068		
		18.12	0.20	40.0	0.125		
		29.53	0.28	62.5	0.218		
		39.70	0.24	75.0	0.296		
		46.97	0.16	90.0	0.348		
1	200	9.26	0.12	22.5	0.067		
		19.34	0.12	40.0	0.141		
		38.44	0.16	62.5	0.284		
		57.86	0.12	75.0	0.421		
		75.17	0.12	90.0	0.559		
1	300	13.18	0.24	22.5	0.092		
		27.55	0.20	40.0	0.203		
		58.90	0.24	62.5	0.437		
		85.03	0.20	75.0	0.623		
				90.0	N.P.		

TABLE 19: PHASE I-B RESULTS FOR IMPERMEABLE MEMBRANE CANISTER (CON'T):

RESULTS, CONFIGURATION NO. 4 WITH LiOH IN CANISTER:

TEST NO.	DEPTH	MTH.P. PRESS. (CM. H2O)	CAN. PRESS. (CM. H20)	RMV (L.)	MAX. WOB (KG. M./L.)	TEMP. (Y/N) (CM. H2O)	COMMENT (Y/N) (CM. H20)
-----	-----	------	------	-----	----	----	--------
4	0	5.62	0.21	22.5	0.024		WOB/ CAN.
		8.30	0.42	40.0	0.042		DUR. TEST,
		11.78	0.64	62.5	0.072		Arc Temp.
		14.24	0.71	75.0	0.093		= 40 deg. F.
		17.97	0.97	90.0	0.165		
4	100	7.81	0.33	22.5	0.054		
		15.17	0.41	40.0	0.109		
		29.22	1.25	62.5	0.212		
		40.42	1.43	75.0	0.294		
		52.93	1.66	90.0	0.391		
4	200	11.93	0.22	22.5	0.084		
		25.98	0.54	40.0	0.195		
		54.06	1.19	62.5	0.387		
		65.88	1.03	75.0	0.498		
		91.65	1.77	90.0	0.703		
4	300	18.54	0.41	22.5	0.131		
		36.18	0.81	40.0	0.347		
		70.29	1.12	62.5	0.537		
		98.33	1.69	75.0	0.758		
		121.52	1.98	90.0	0.963		

Table 20: Design Parameter Comparison

	Phase I Rankings			Phase I-B Rankings		
Design Parameters Configuration Nos.)	Canister Efficeincies	WOB	Canister Delta P's	Design Parameters Configuration Nos.)	Canister Efficiencies	WOB
Axial (3)	1	1	7	Axial (3)	1	3
Radial (2,5)	3,-	8,7	3,1	Radial (2,5)	5,4	7,6
Split Bag (1,2,3)	2,3,1	4,8,1	2,3,7	Split Bag (1,2)	-,-	5,7
Single Bag (7,8,9)	-,-,-	2,6,5	6,5,8	Single Bag (7,8)	-,-	1,2
L/D = 0.75 (1)	2	4	2	L/D = 0.75 (1)	3	5
L/D = 2.25 (2)	3	8	3	L/D = 2.25 (2)	5	7
in-out flow (2)	3	7	1	in-out flow (2)	5	7
out-in flow (5)	-	8	3	out-in flow (5)	4	6

CO2 SCRUBBER CANISTER EFFICEINCY

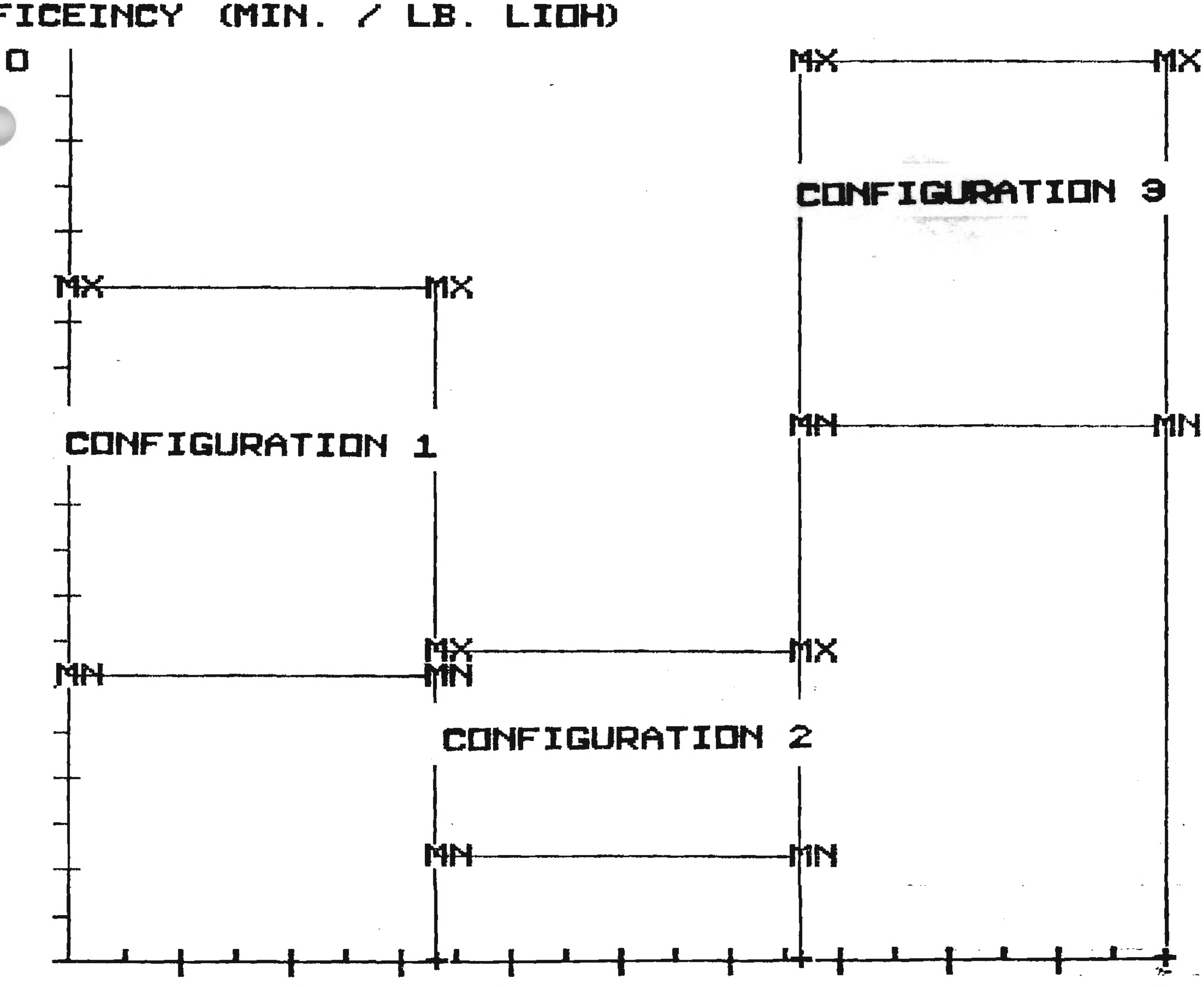


FIGURE 1:

X = MAXIMUM EFFICIENCY OF ALL CANISTER DURATION TESTS.
N = MINIMUM EFFICIENCY OF ALL CANISTER DURATION TESTS.

CO2 SCRUBBER CANISTER EFFICIENCY

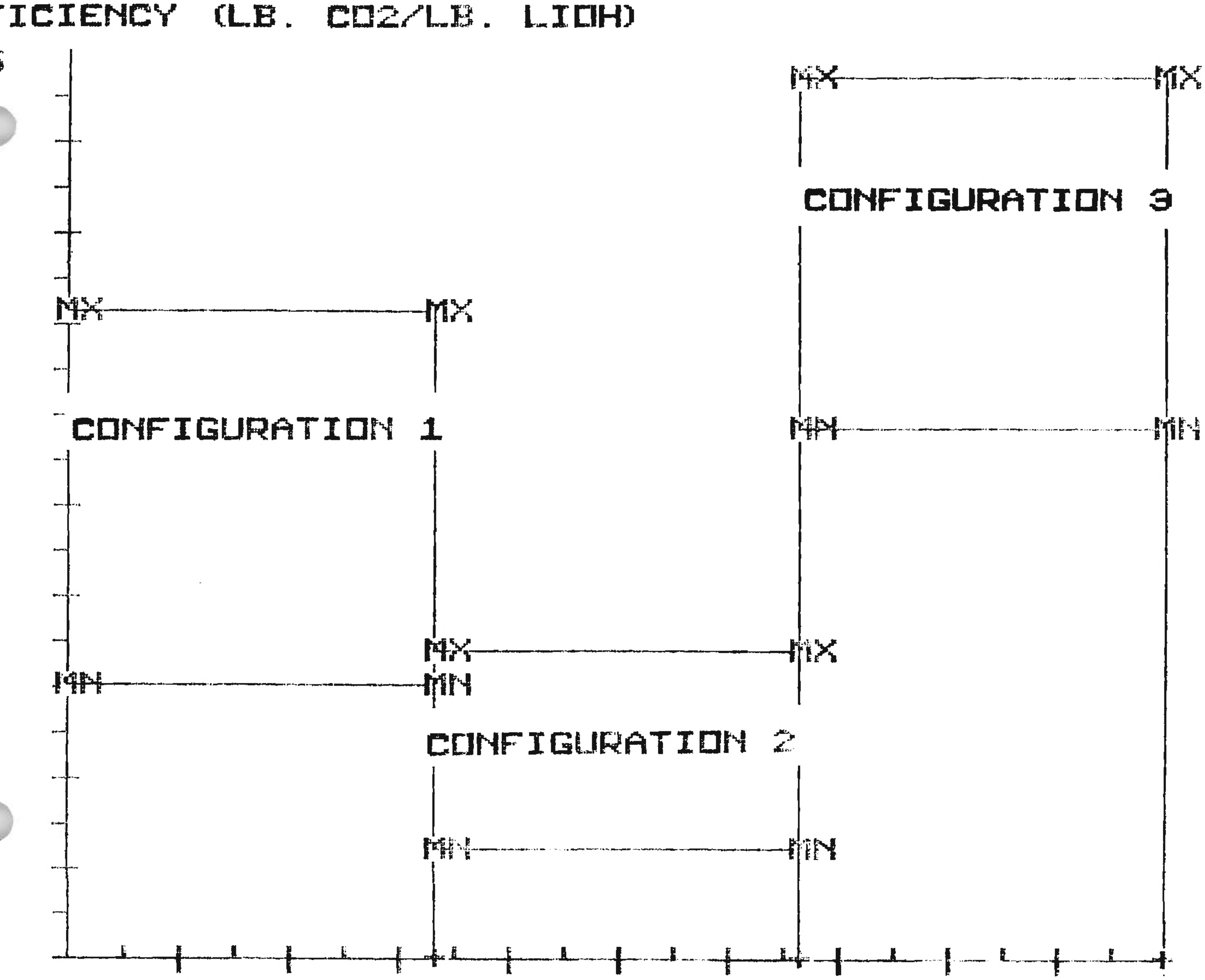


FIGURE 2:

IX = MAXIMUM EFFICIENCY OF ALL CANISTER DURATION TESTS.
IN = MINIMUM EFFICIENCY OF ALL CANISTER DURATION TESTS.

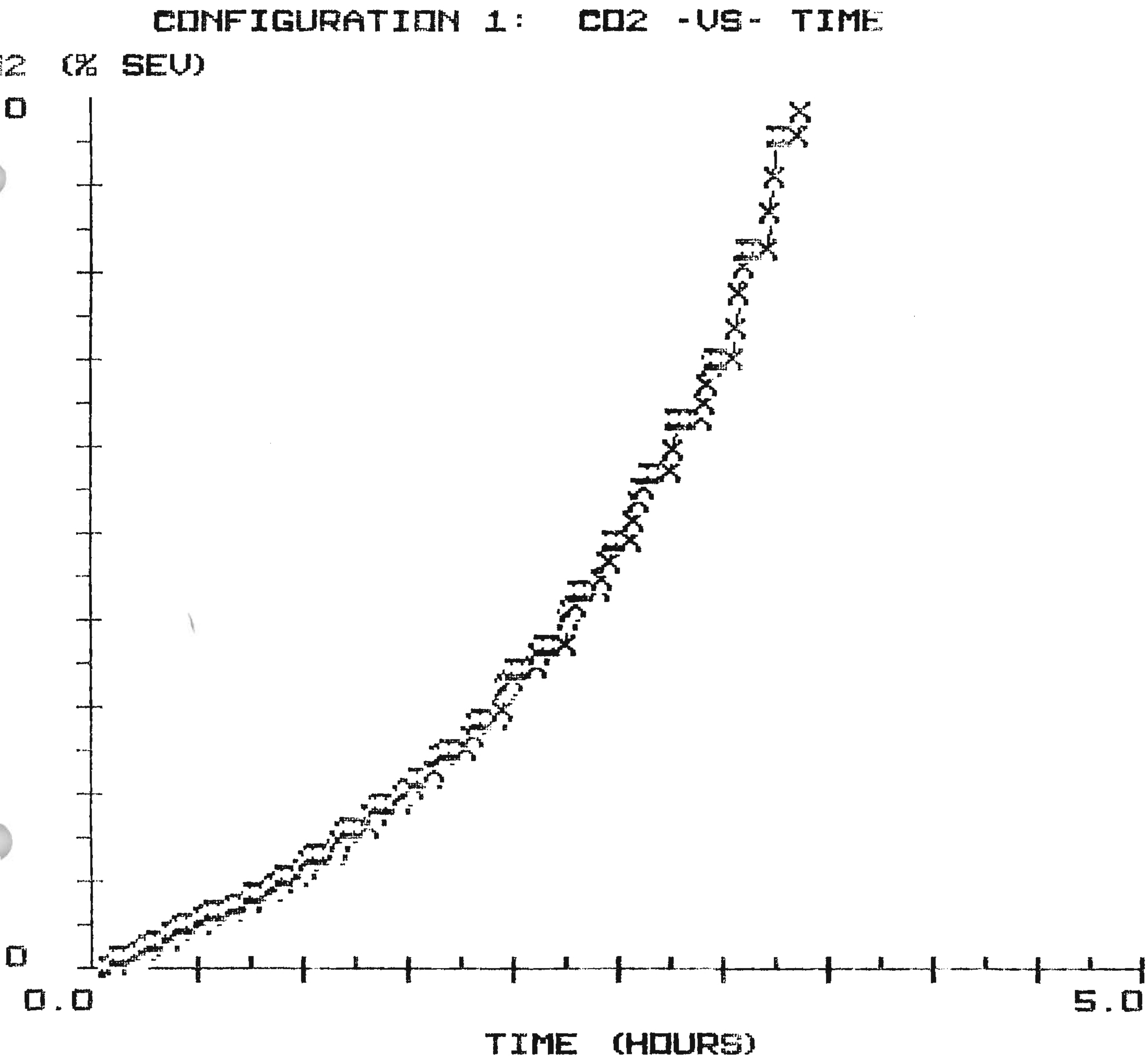


FIGURE 3:

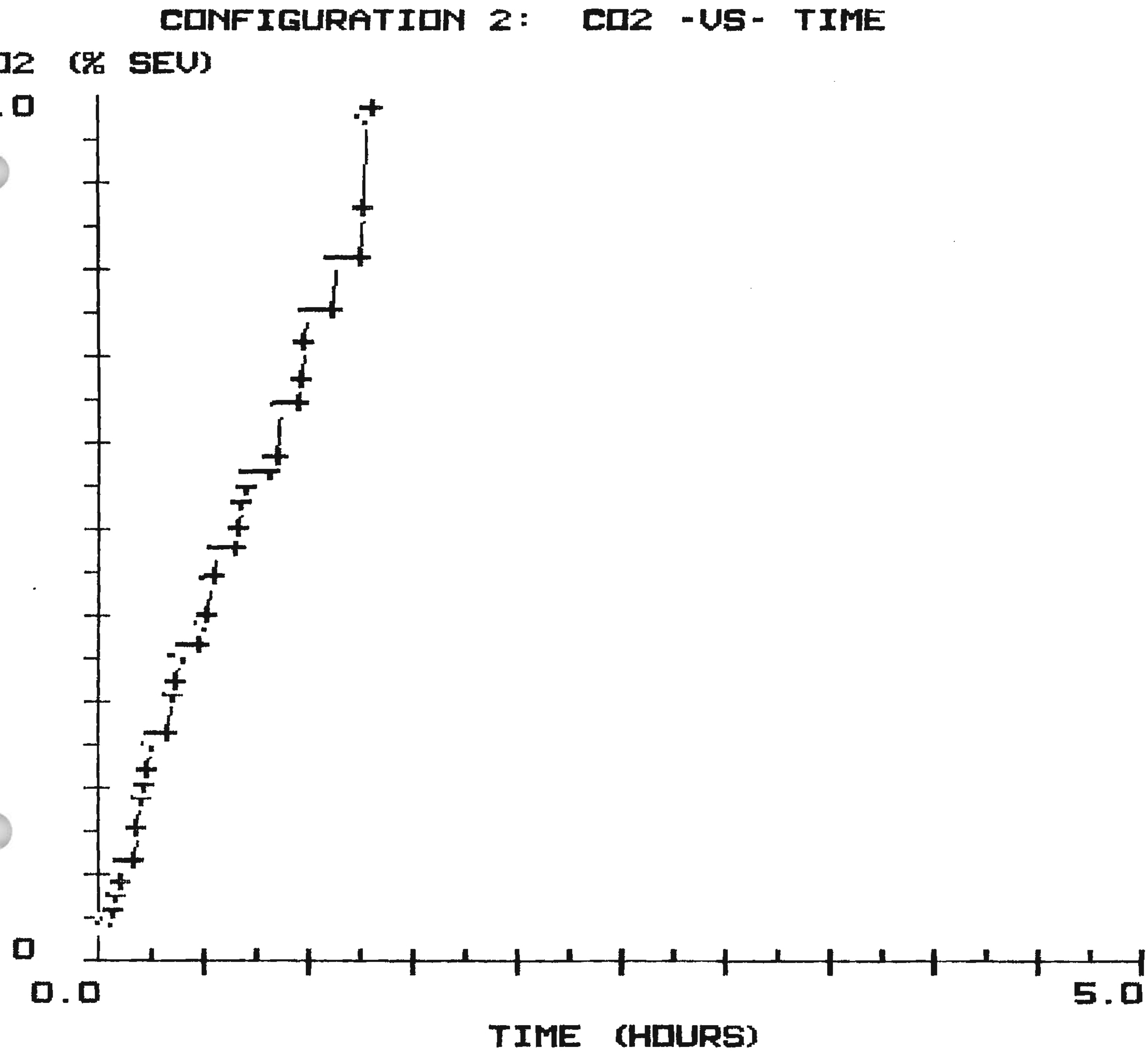


FIGURE 4:

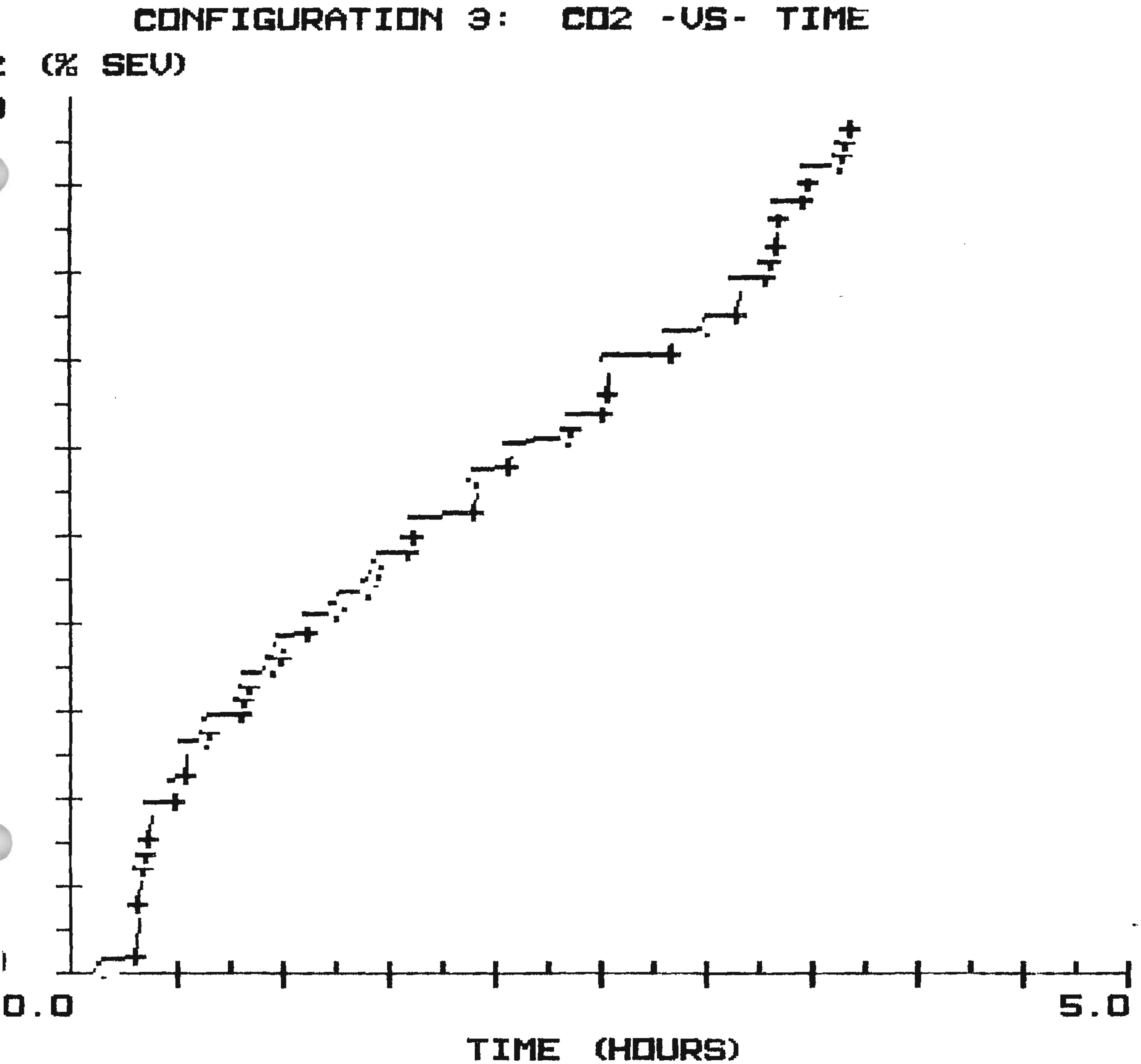


FIGURE 5:

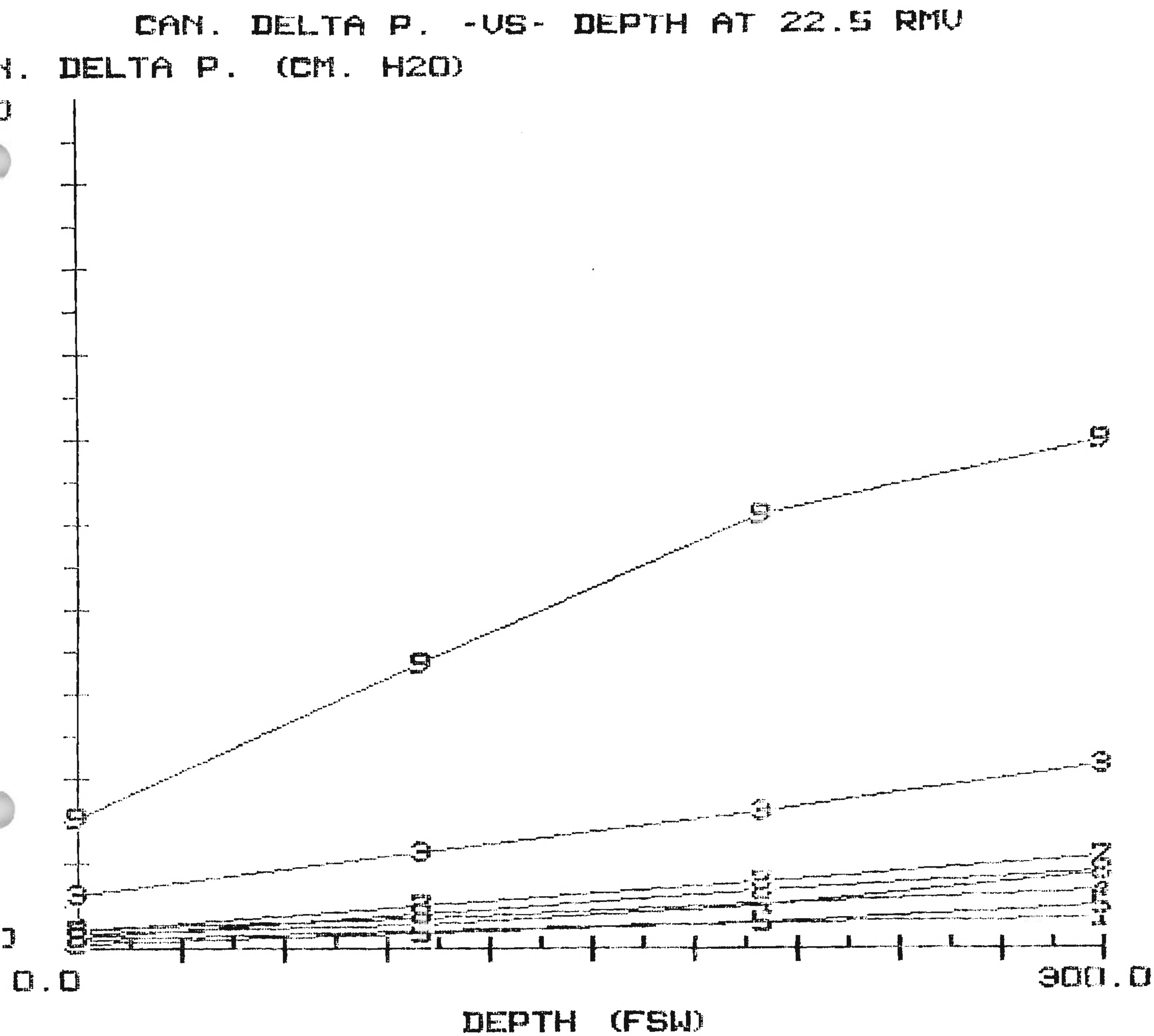


FIGURE 6:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

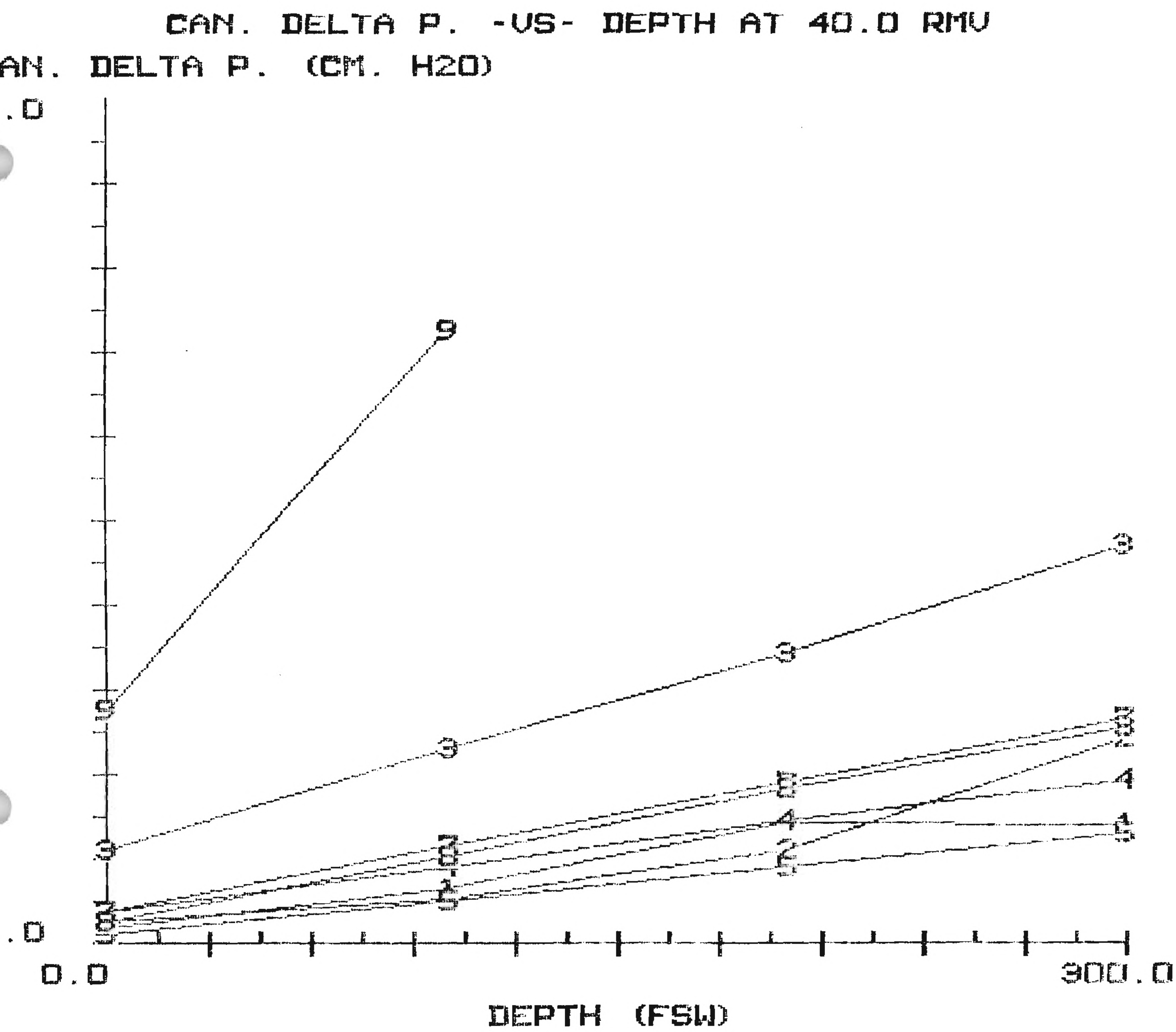


FIGURE 7:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

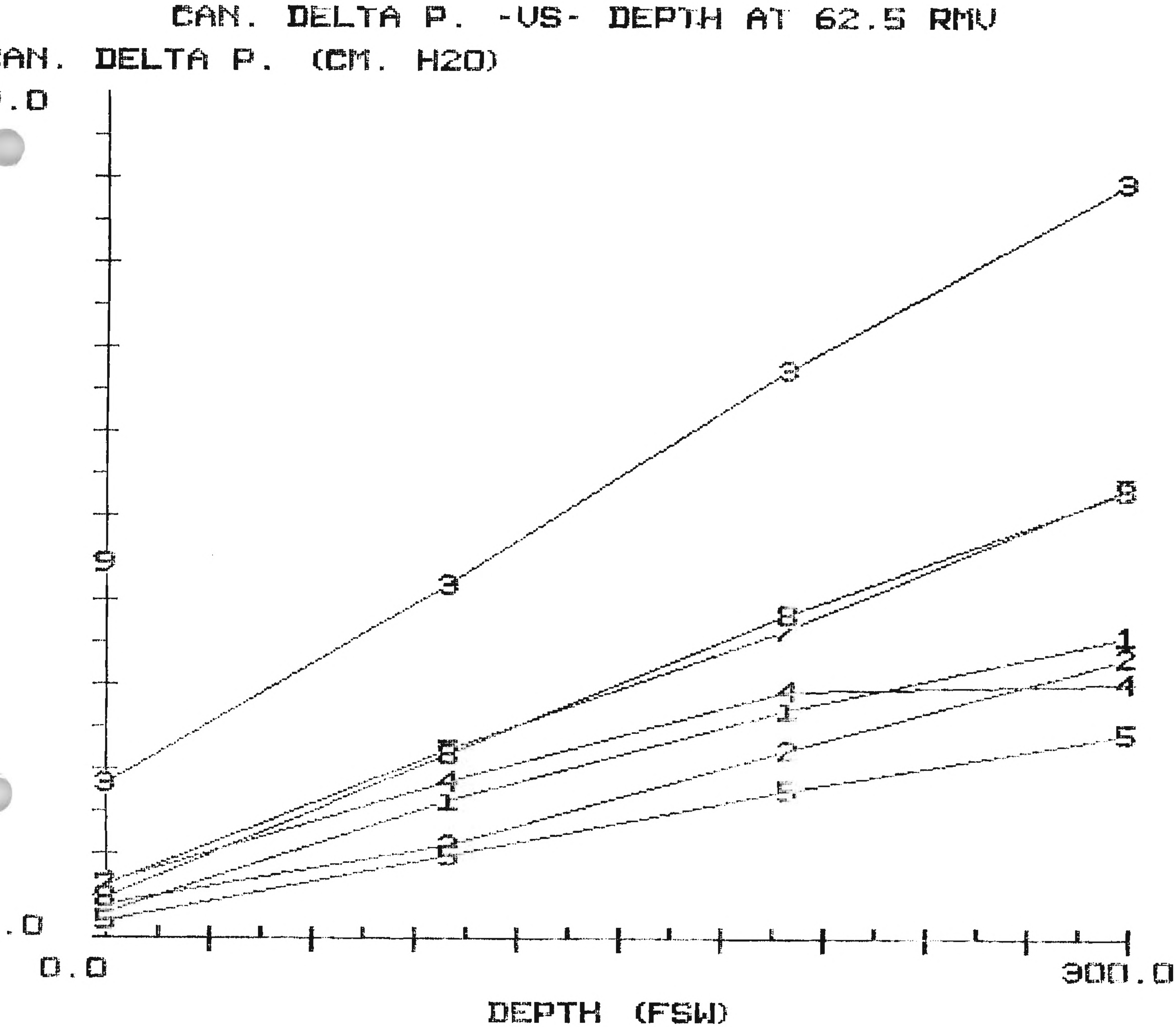


FIGURE 8:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

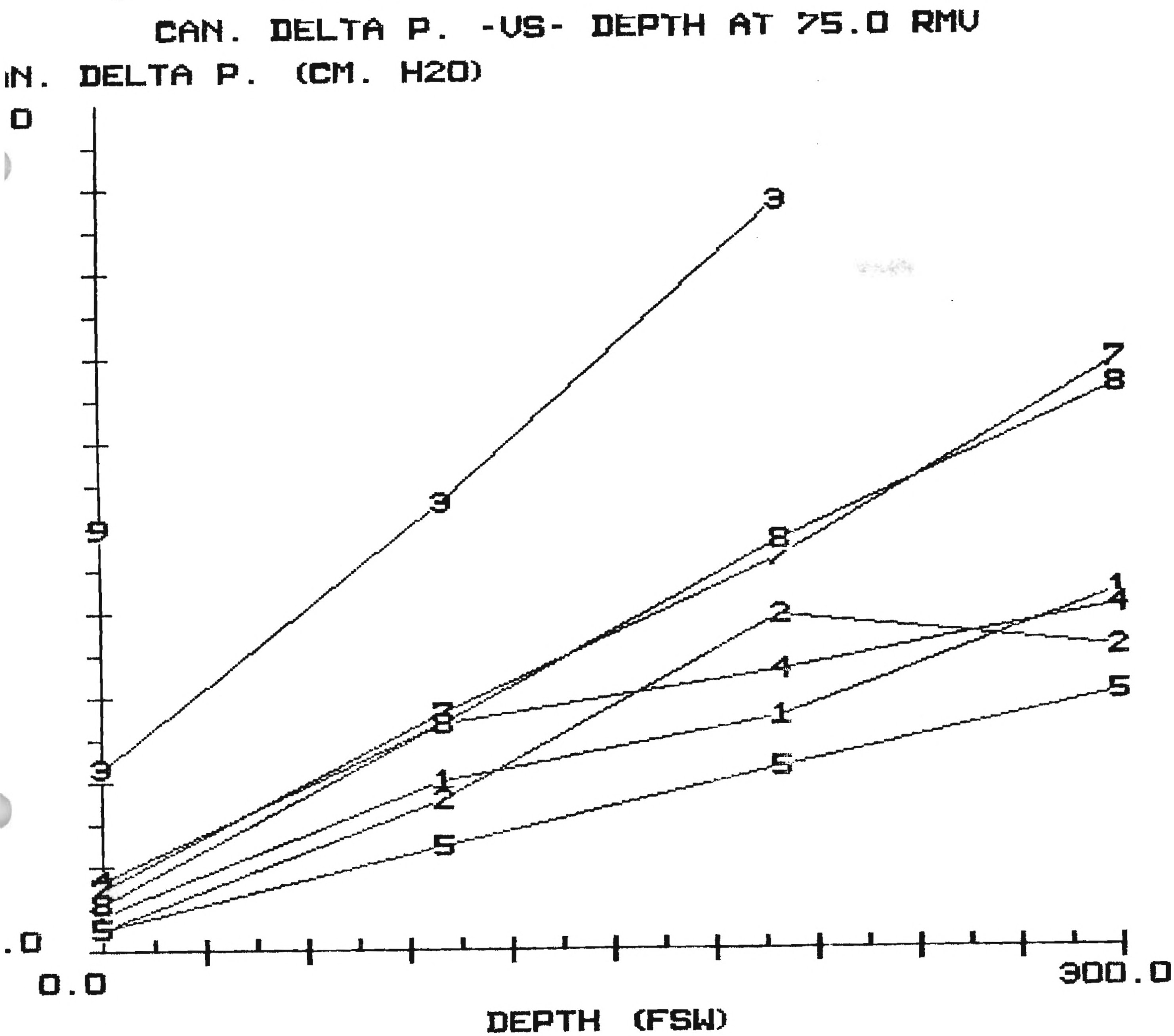


FIGURE 9:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

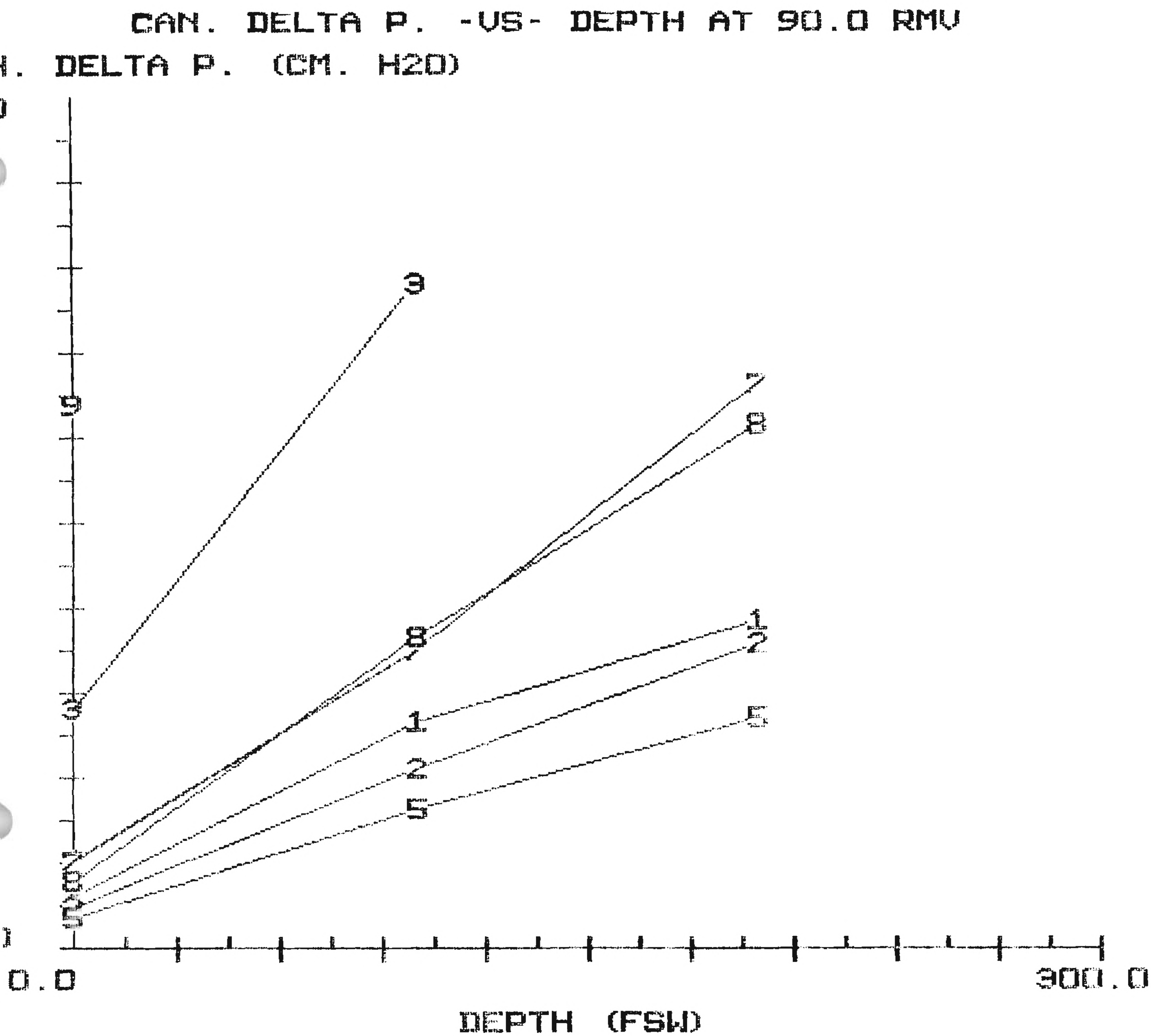


FIGURE 10:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

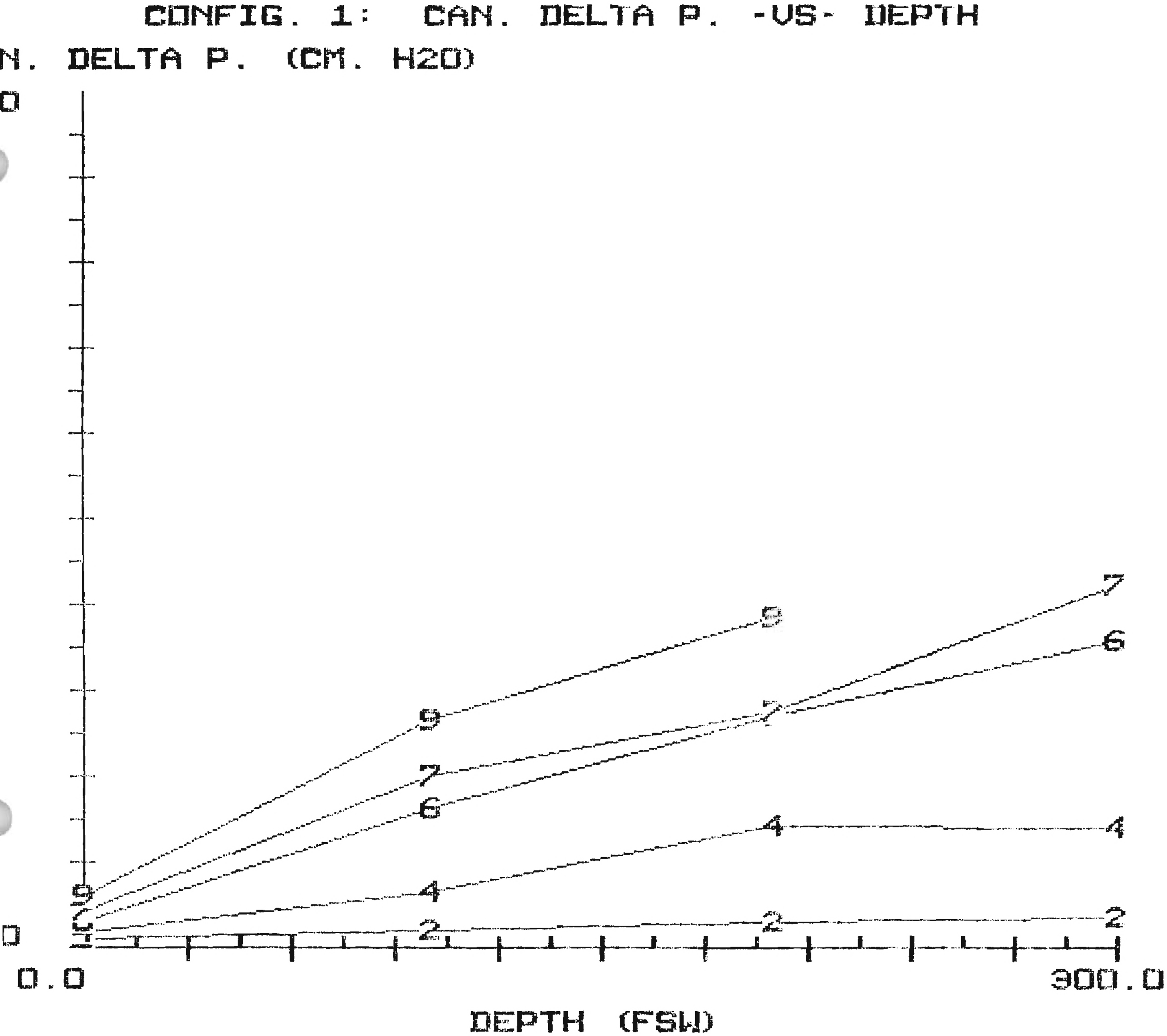


FIGURE 11:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

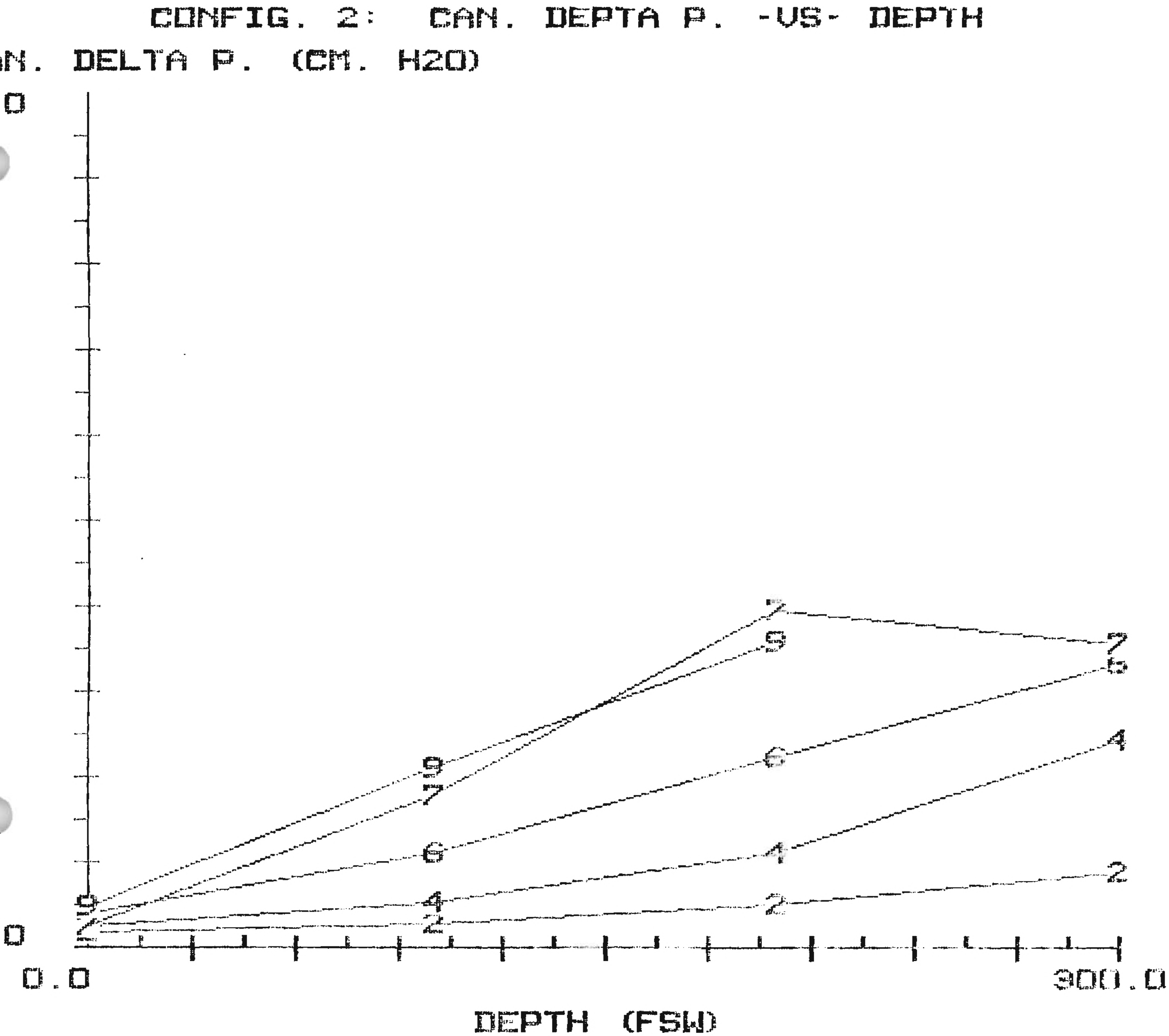


FIGURE 12:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

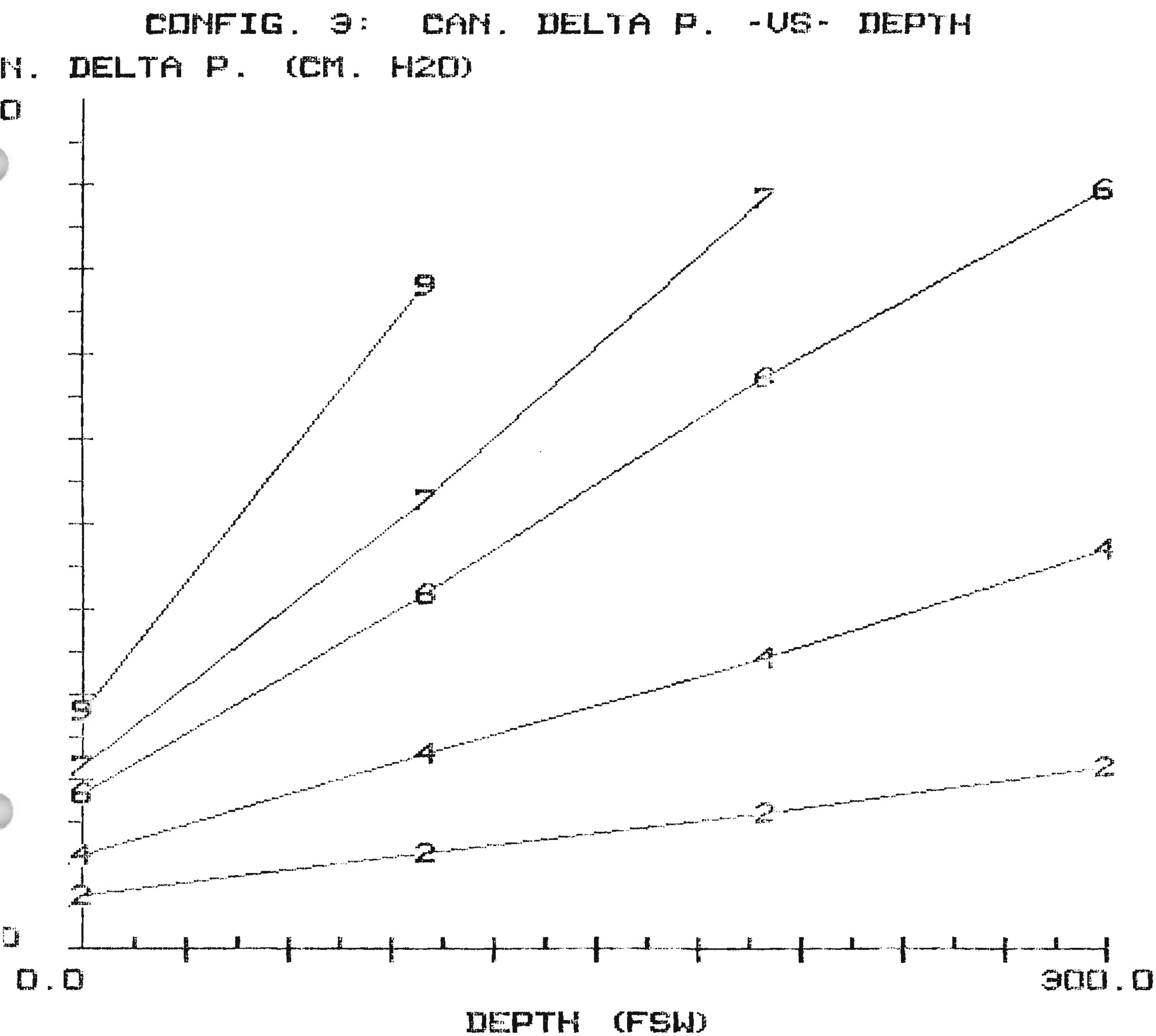


FIGURE 13:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

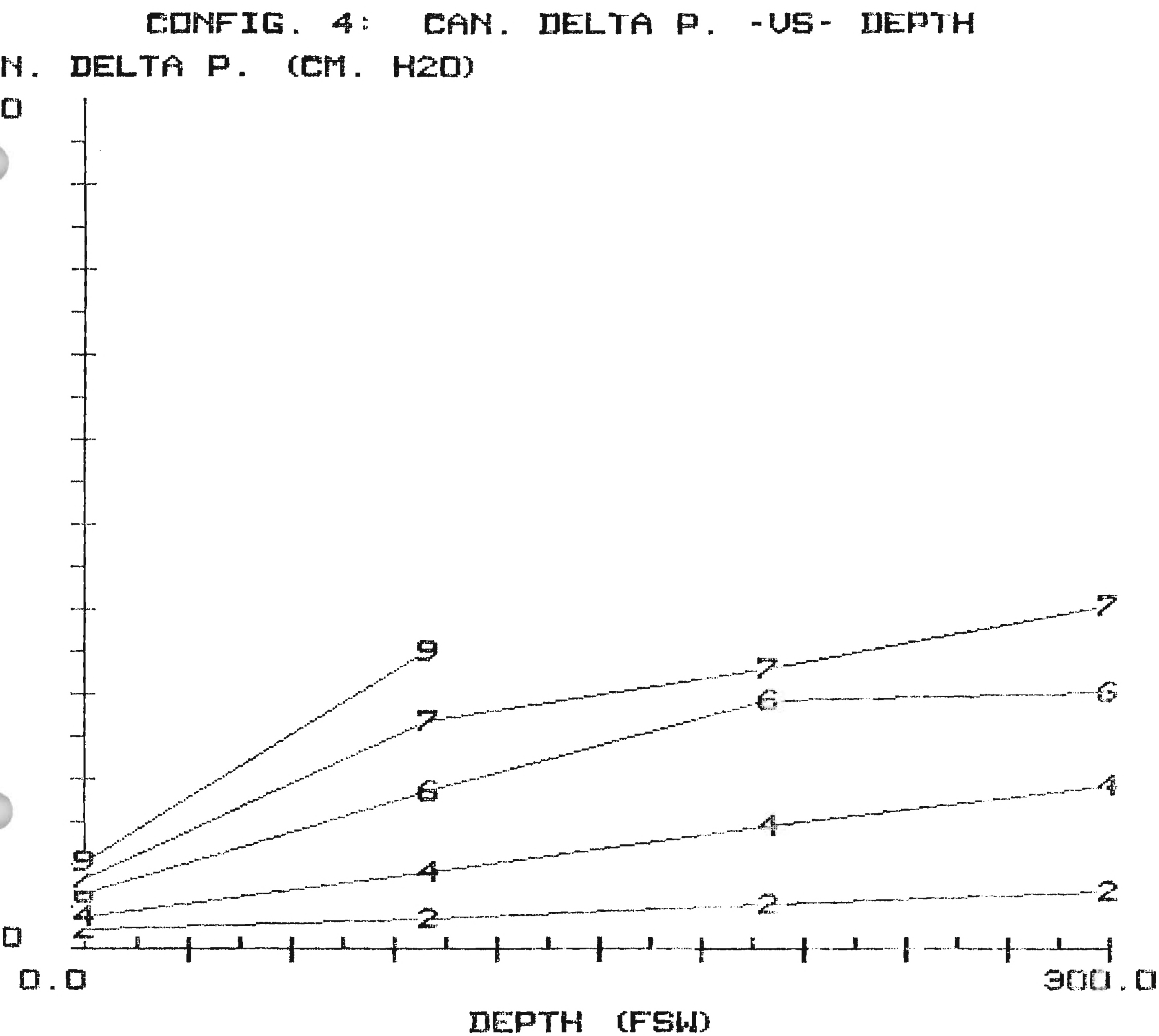


FIGURE 14:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

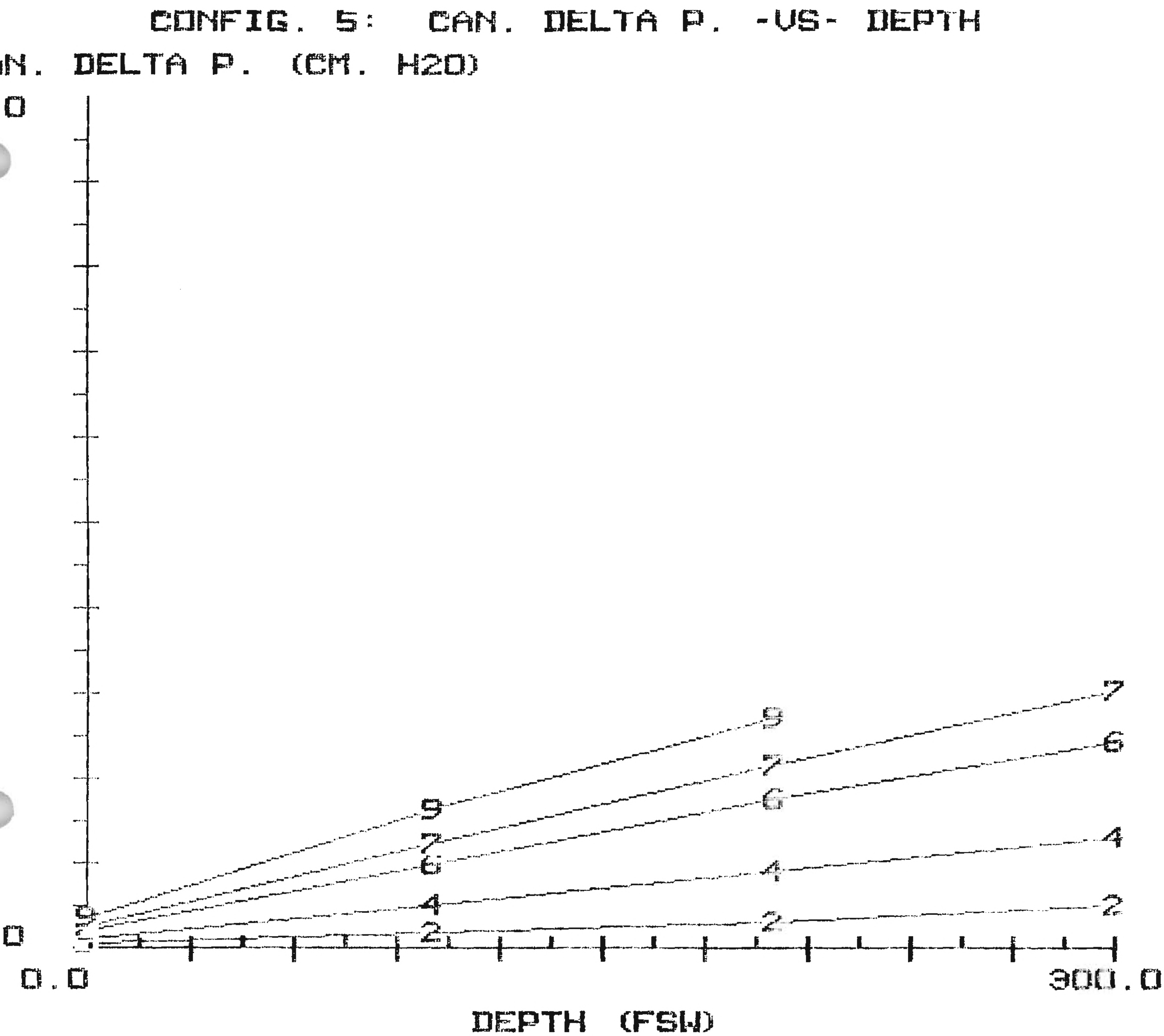


FIGURE 15:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

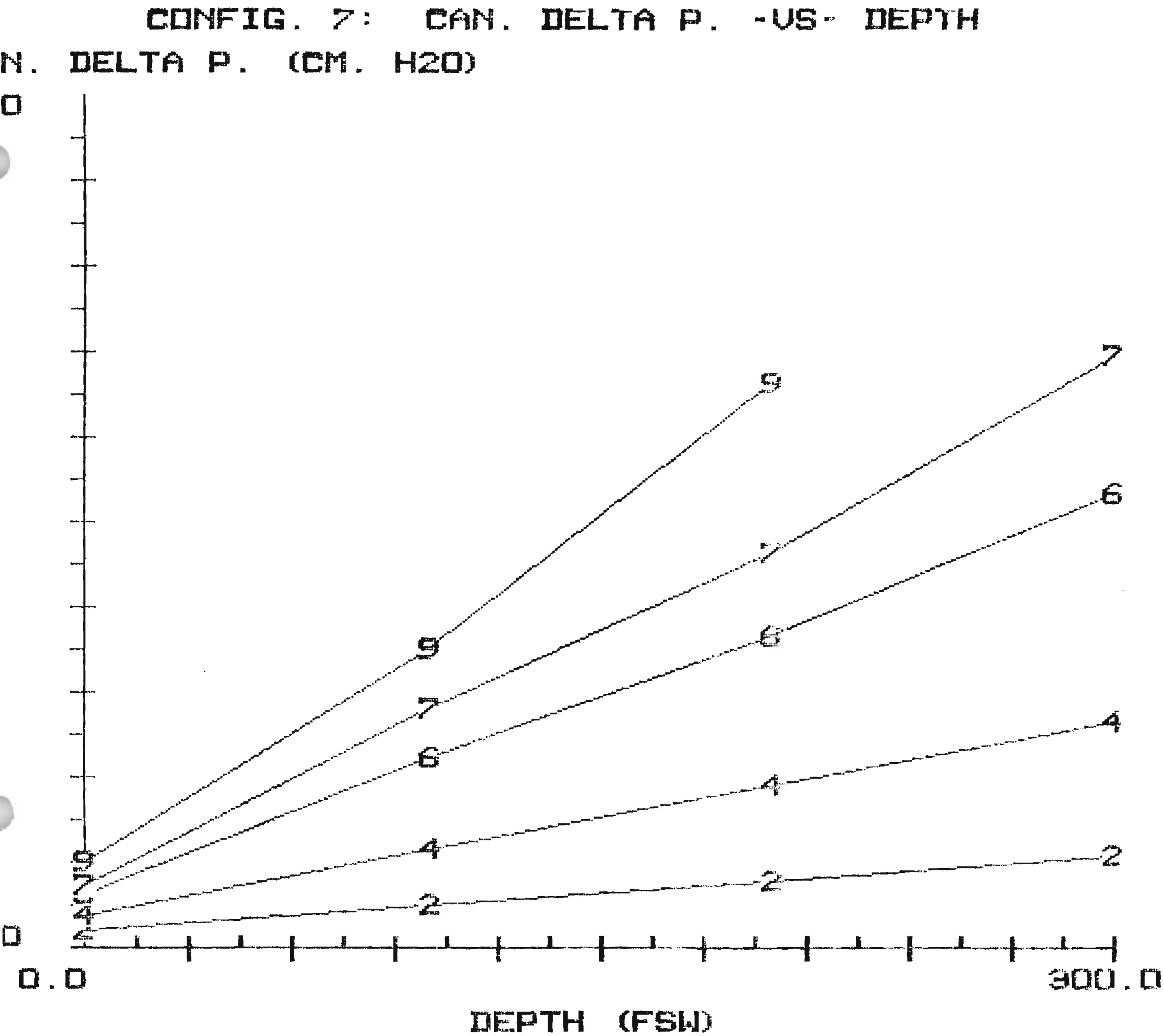


FIGURE 16:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

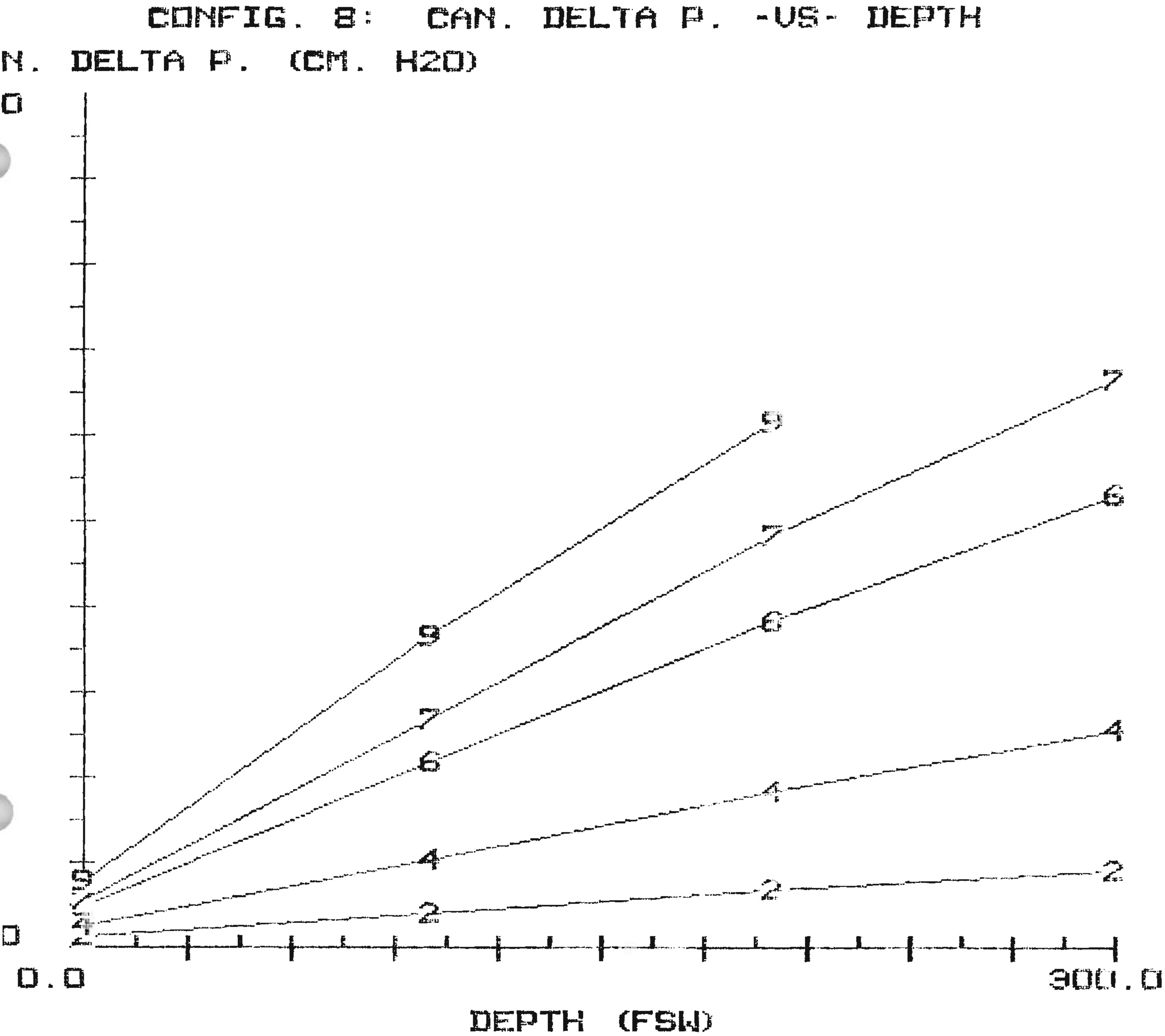


FIGURE 17:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

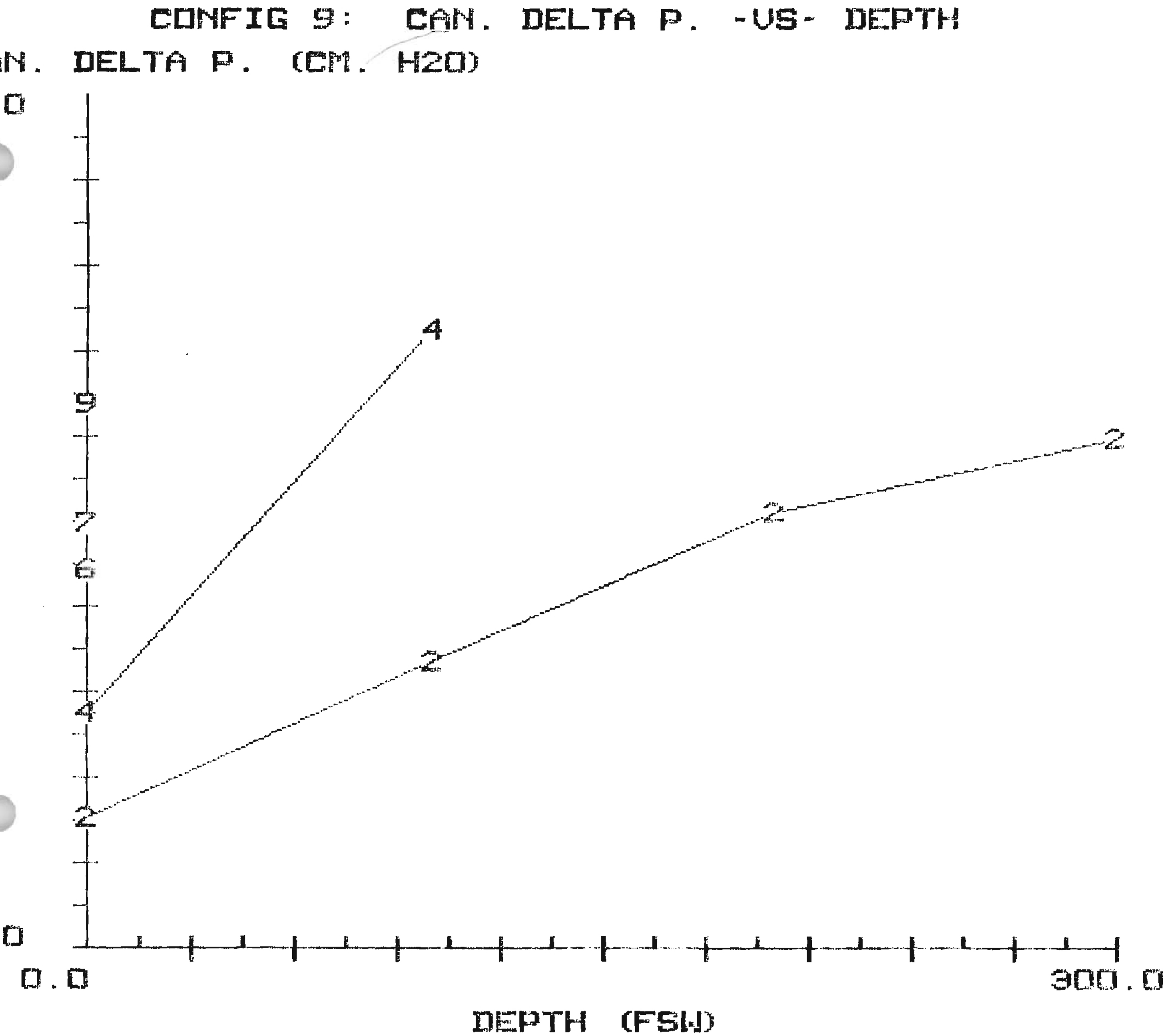


FIGURE 18:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

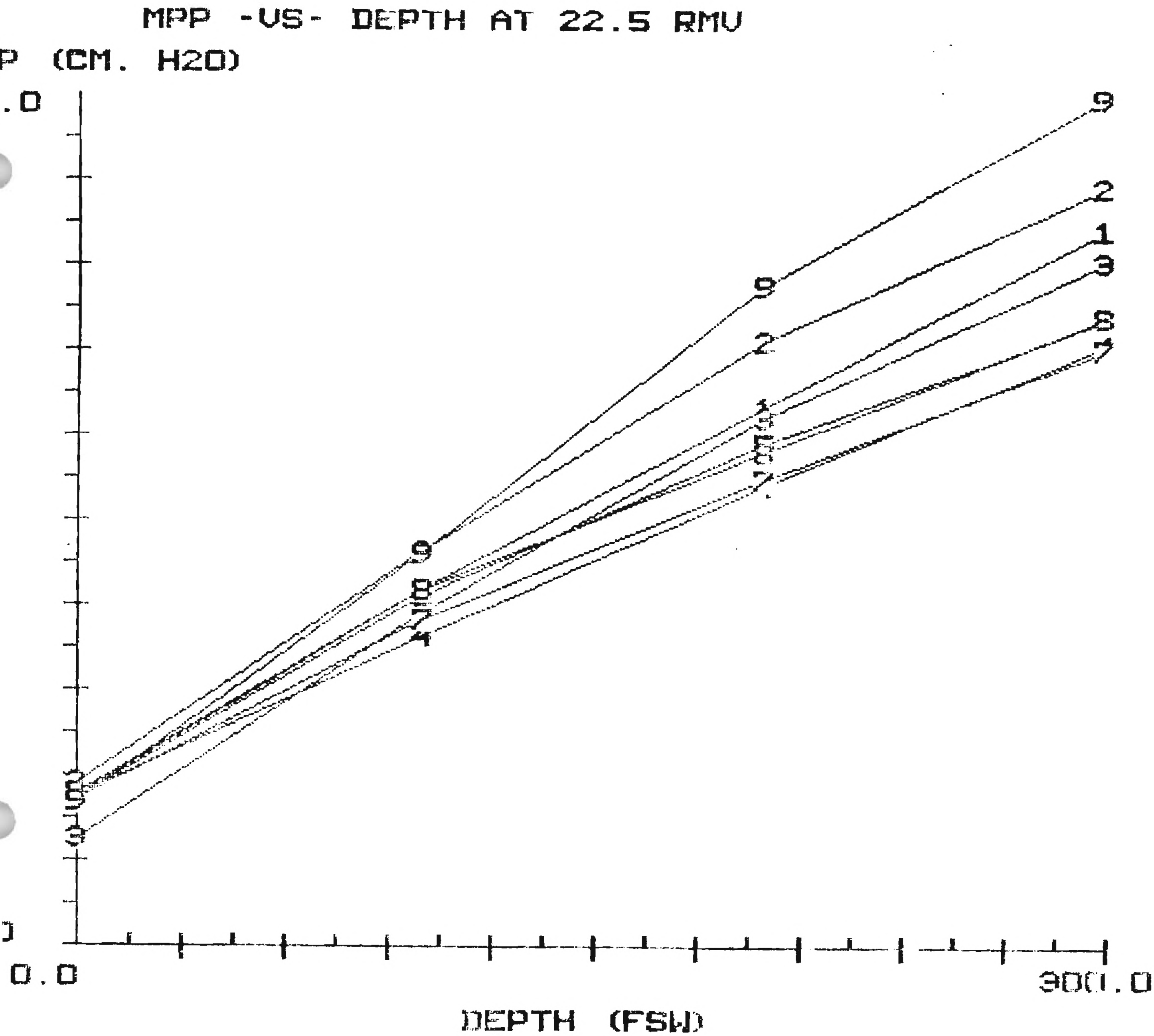


FIGURE 19:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

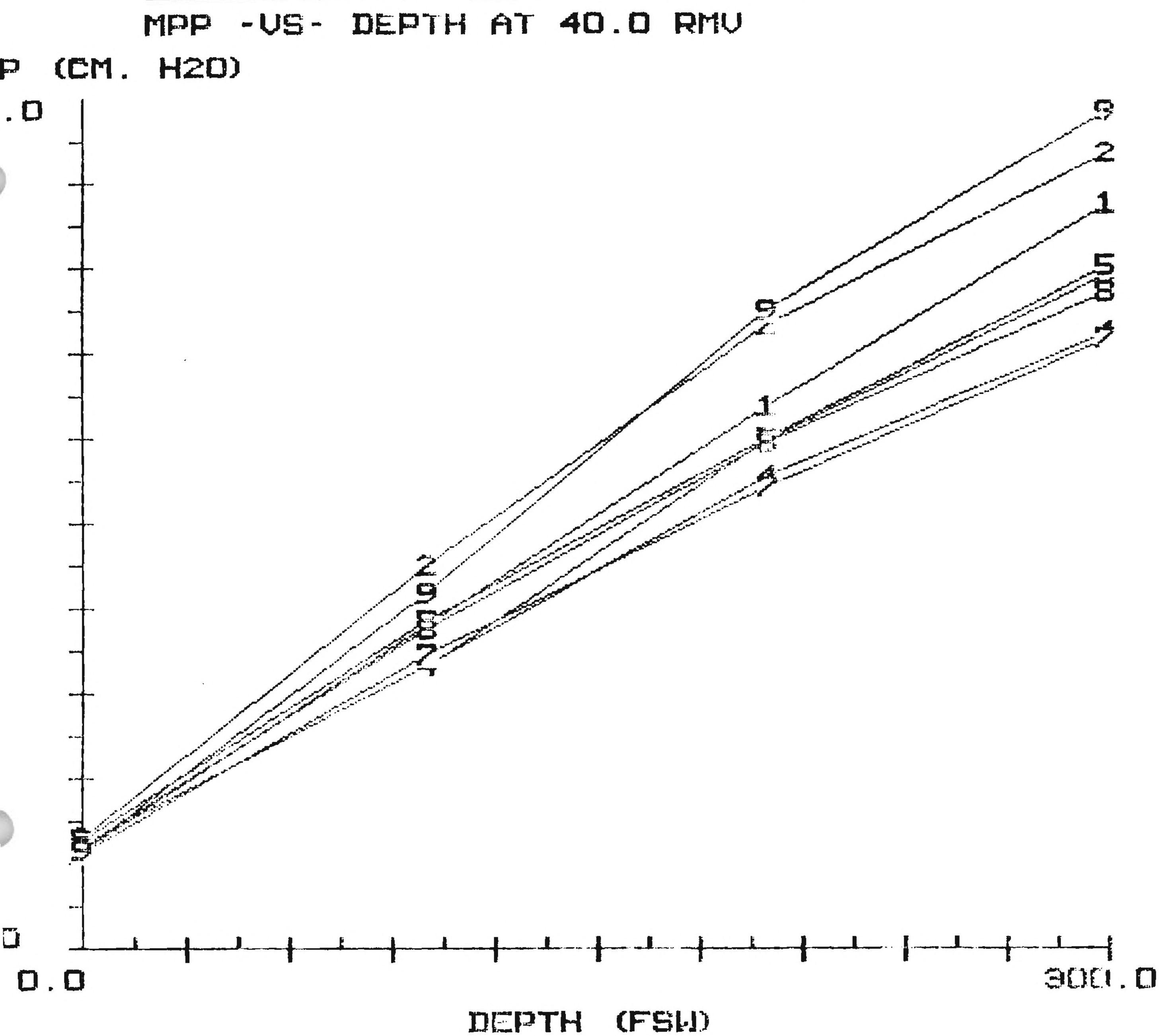


FIGURE 20:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

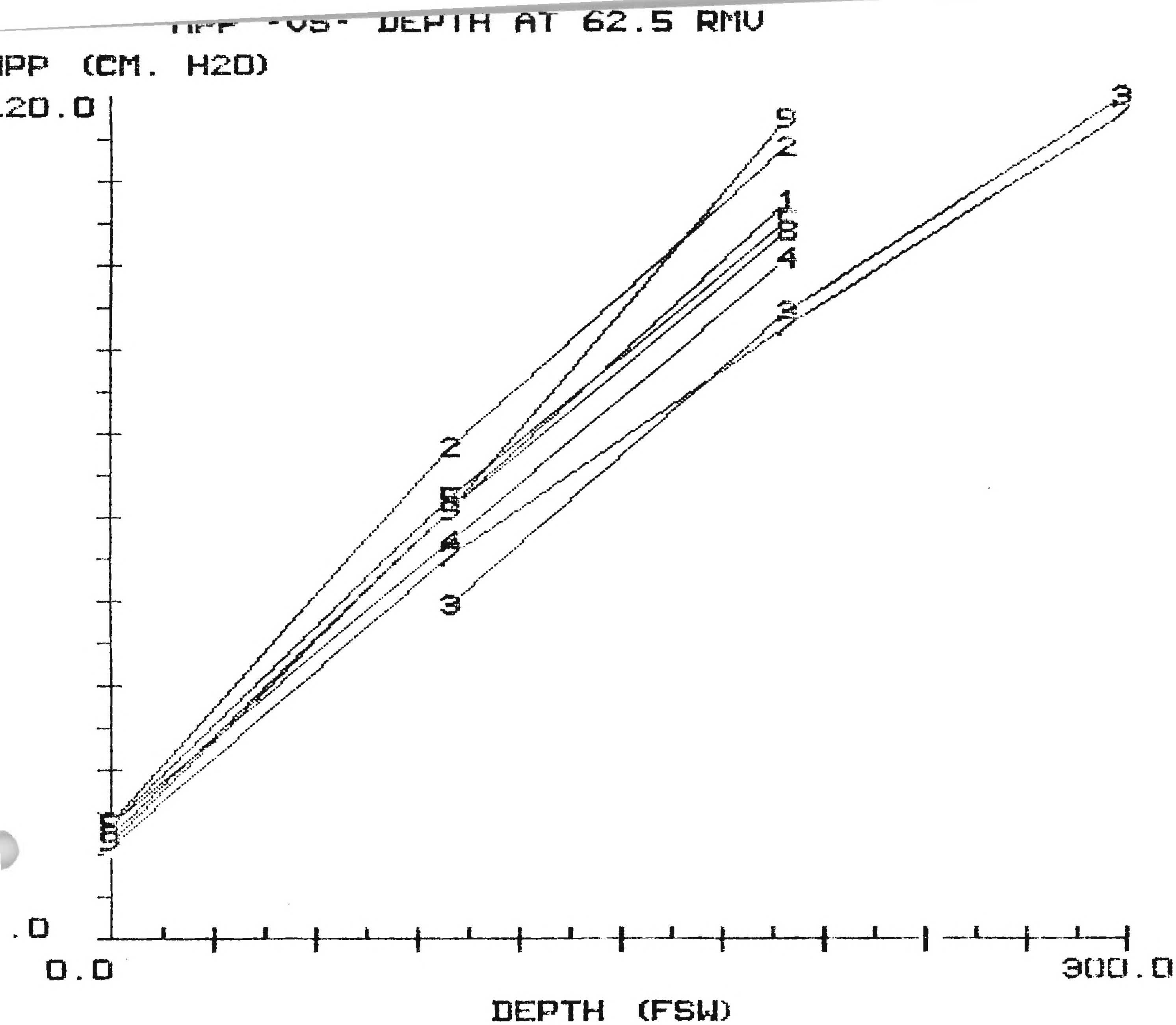


FIGURE 21:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

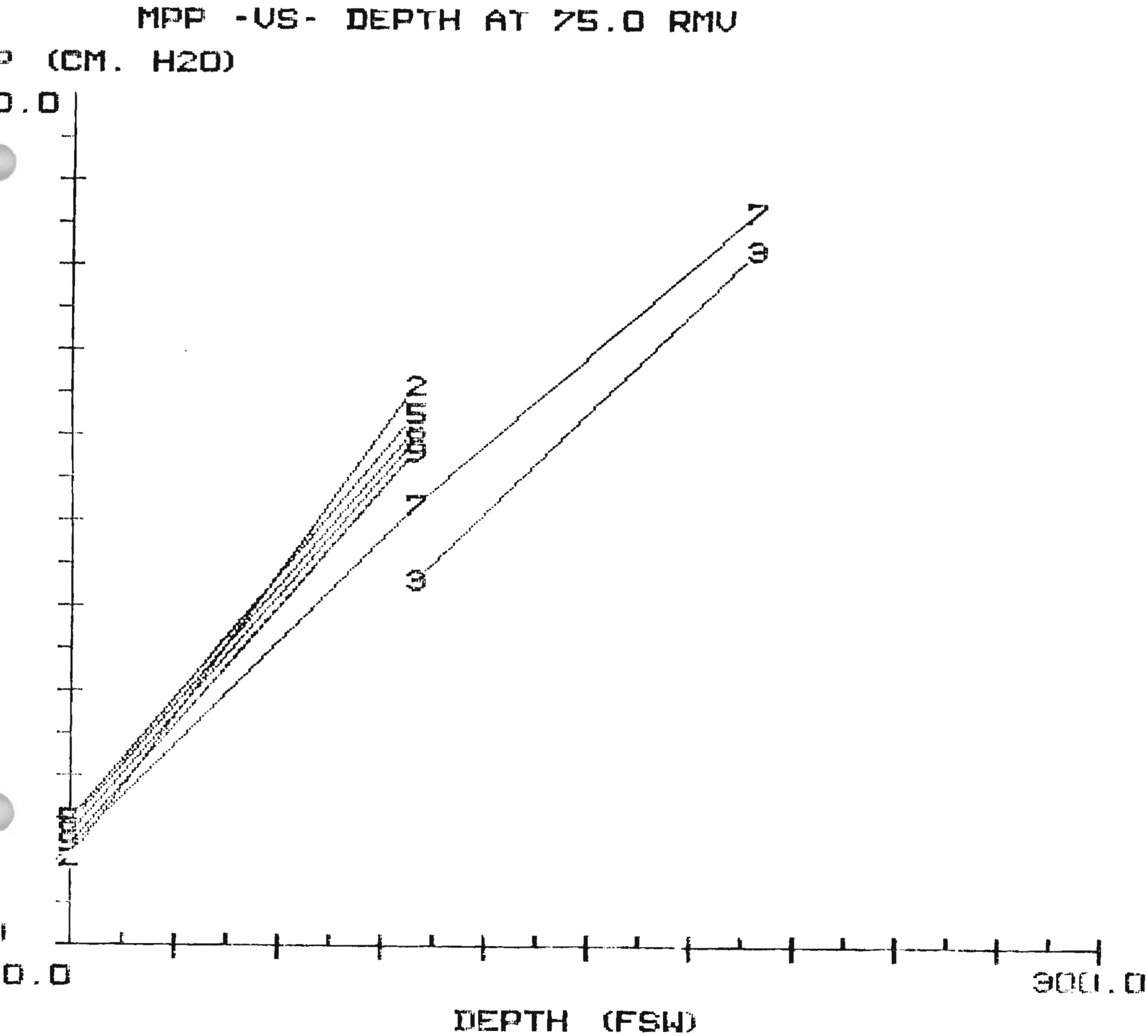


FIGURE 22:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

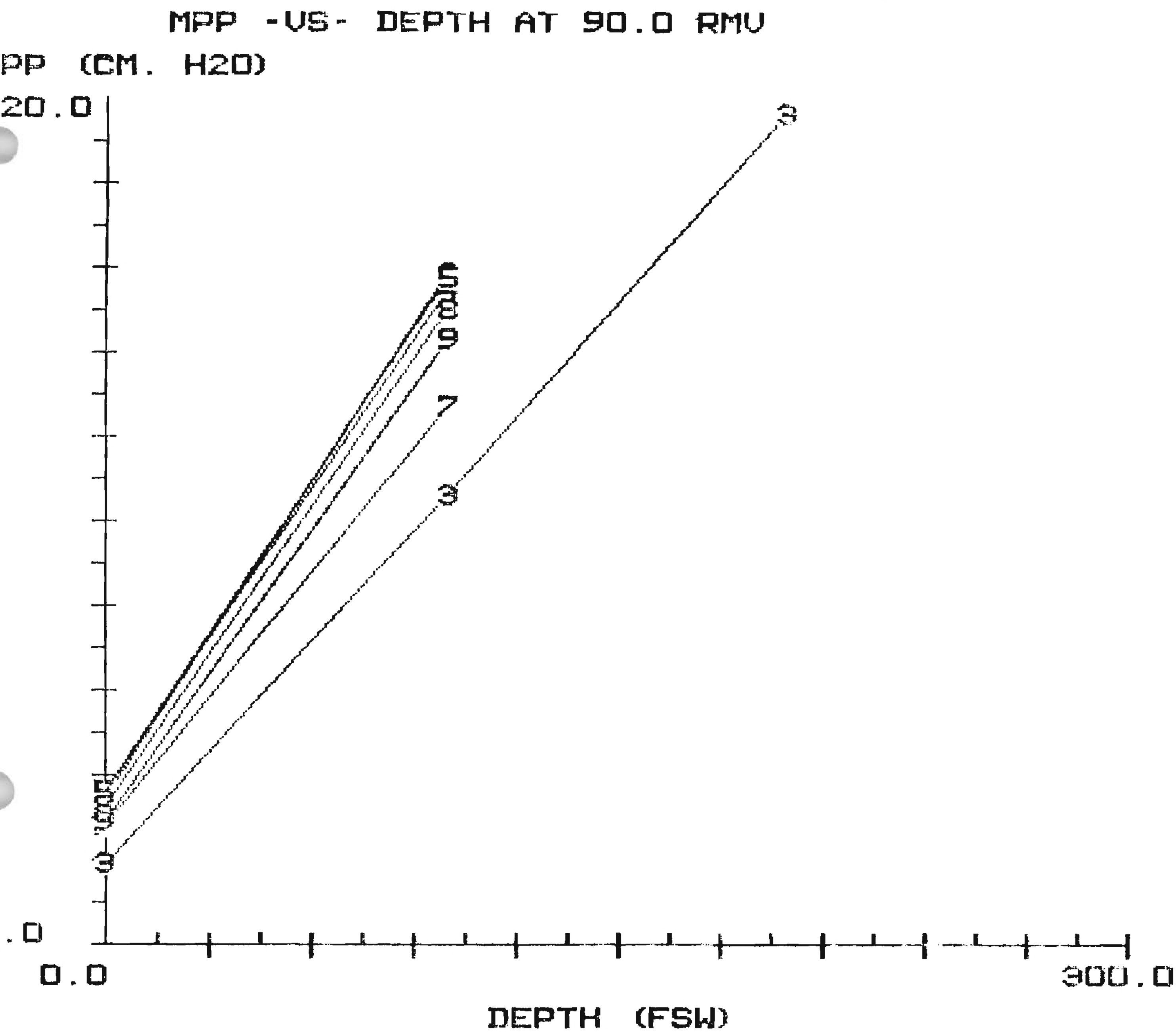


FIGURE 23:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

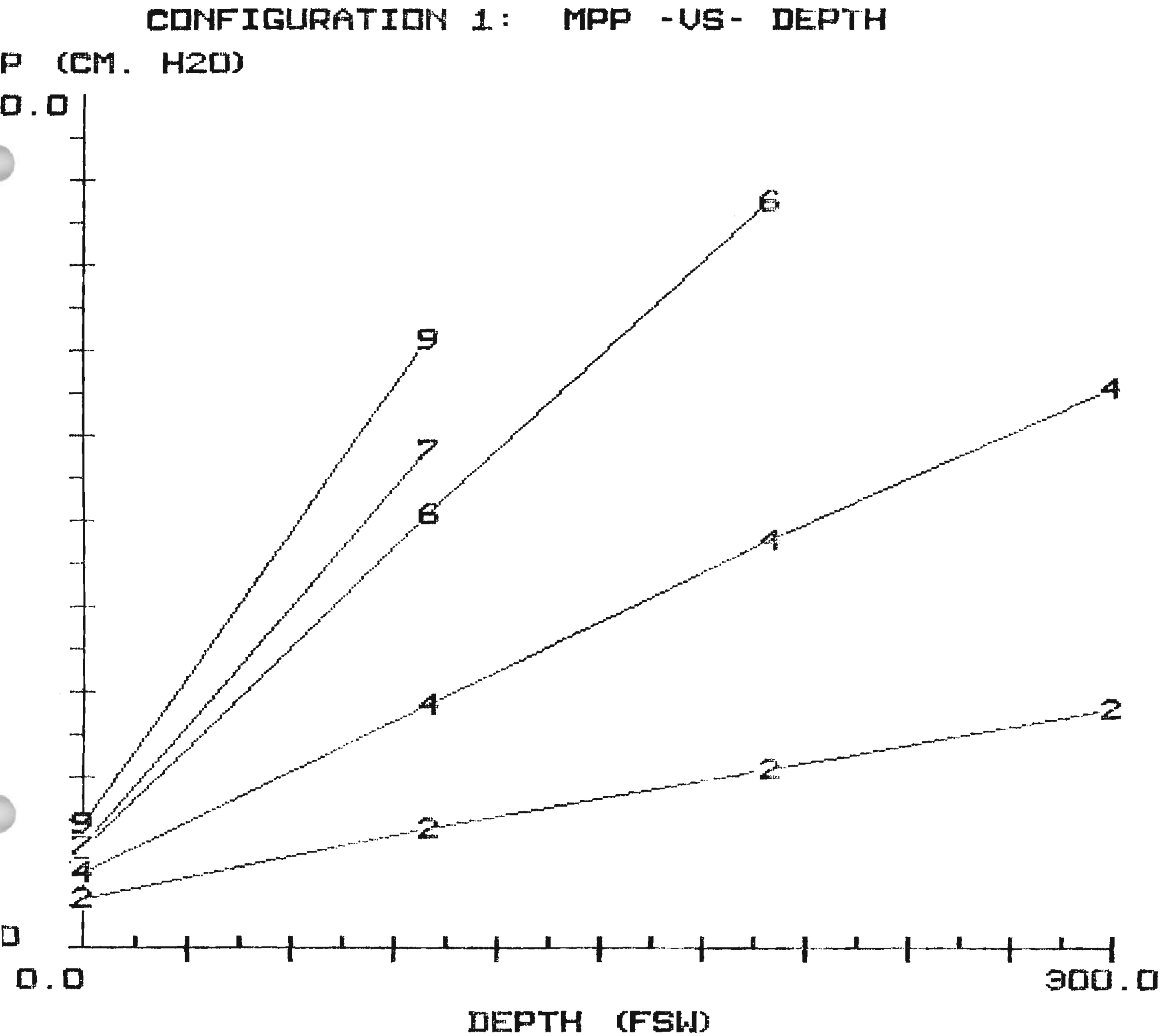


FIGURE 24:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

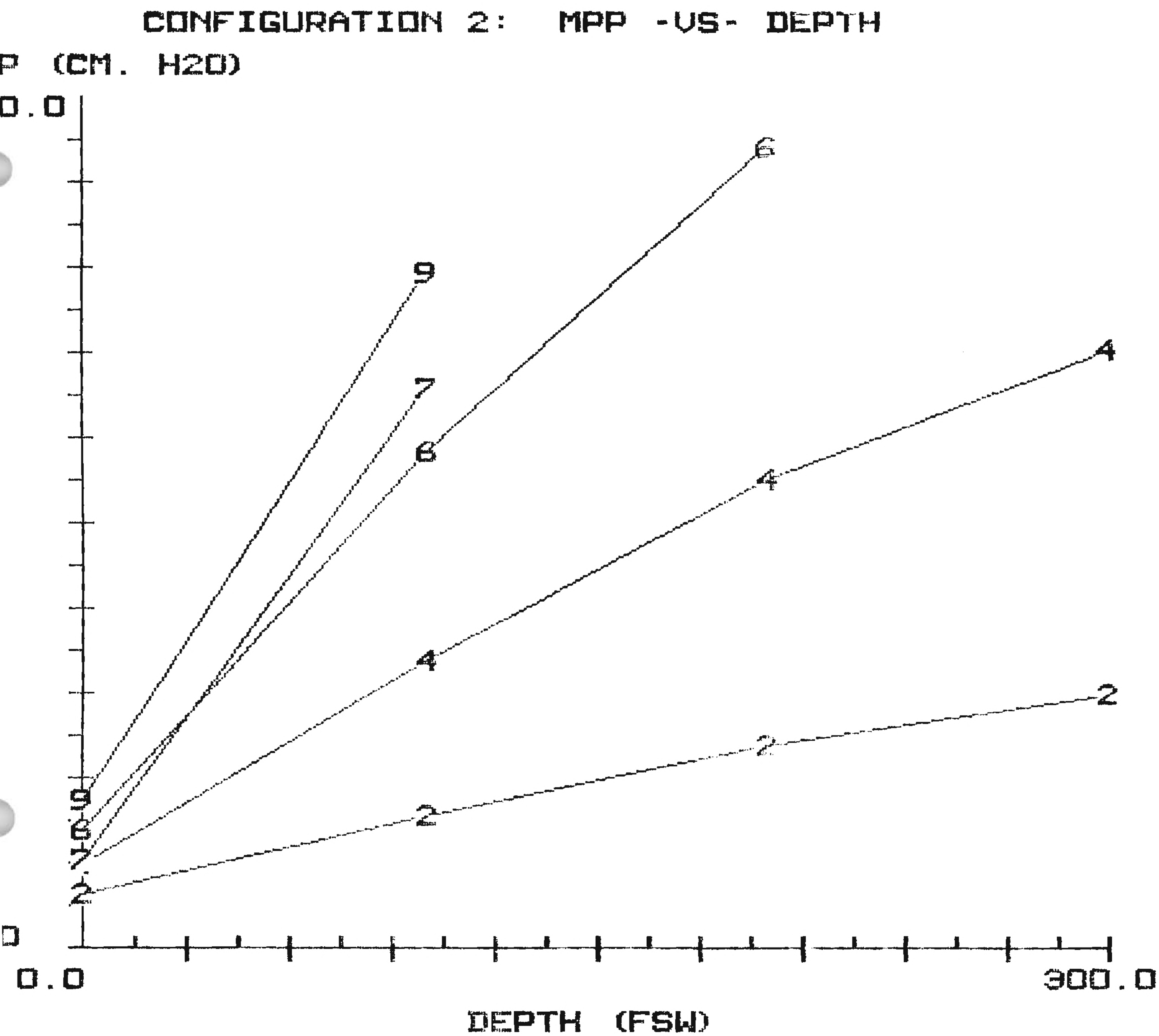


FIGURE 25:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

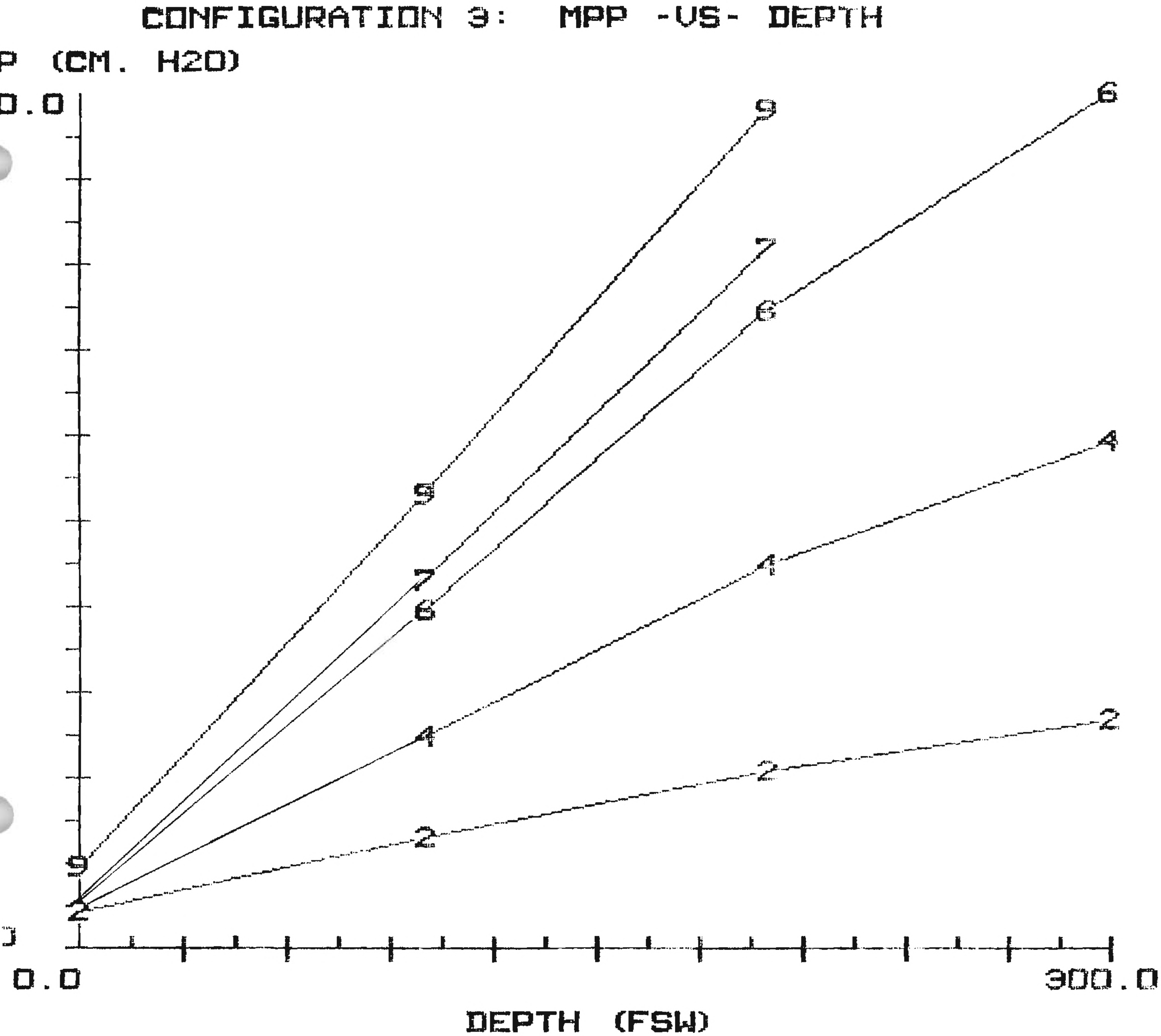


FIGURE 26:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

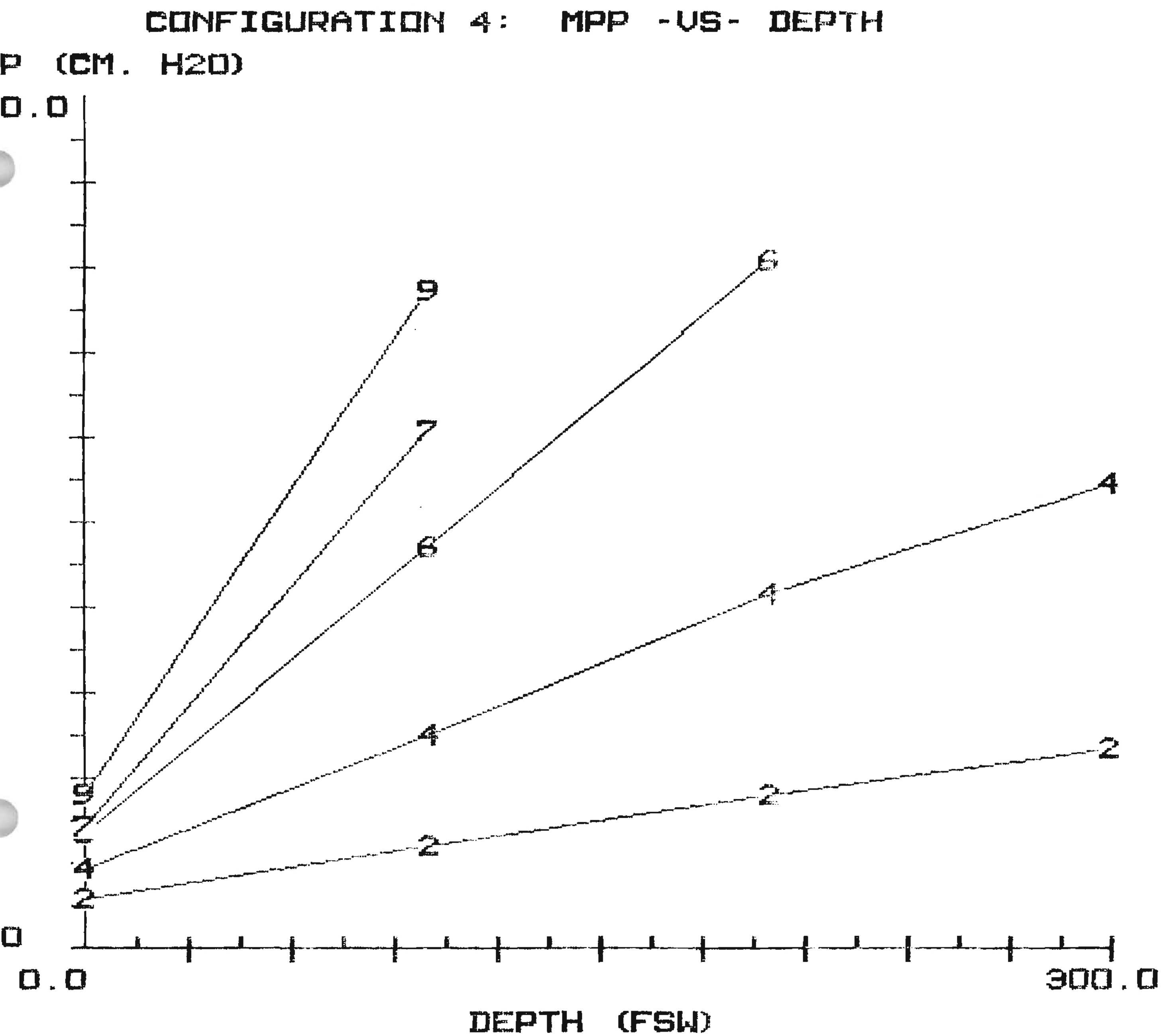


FIGURE 27:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

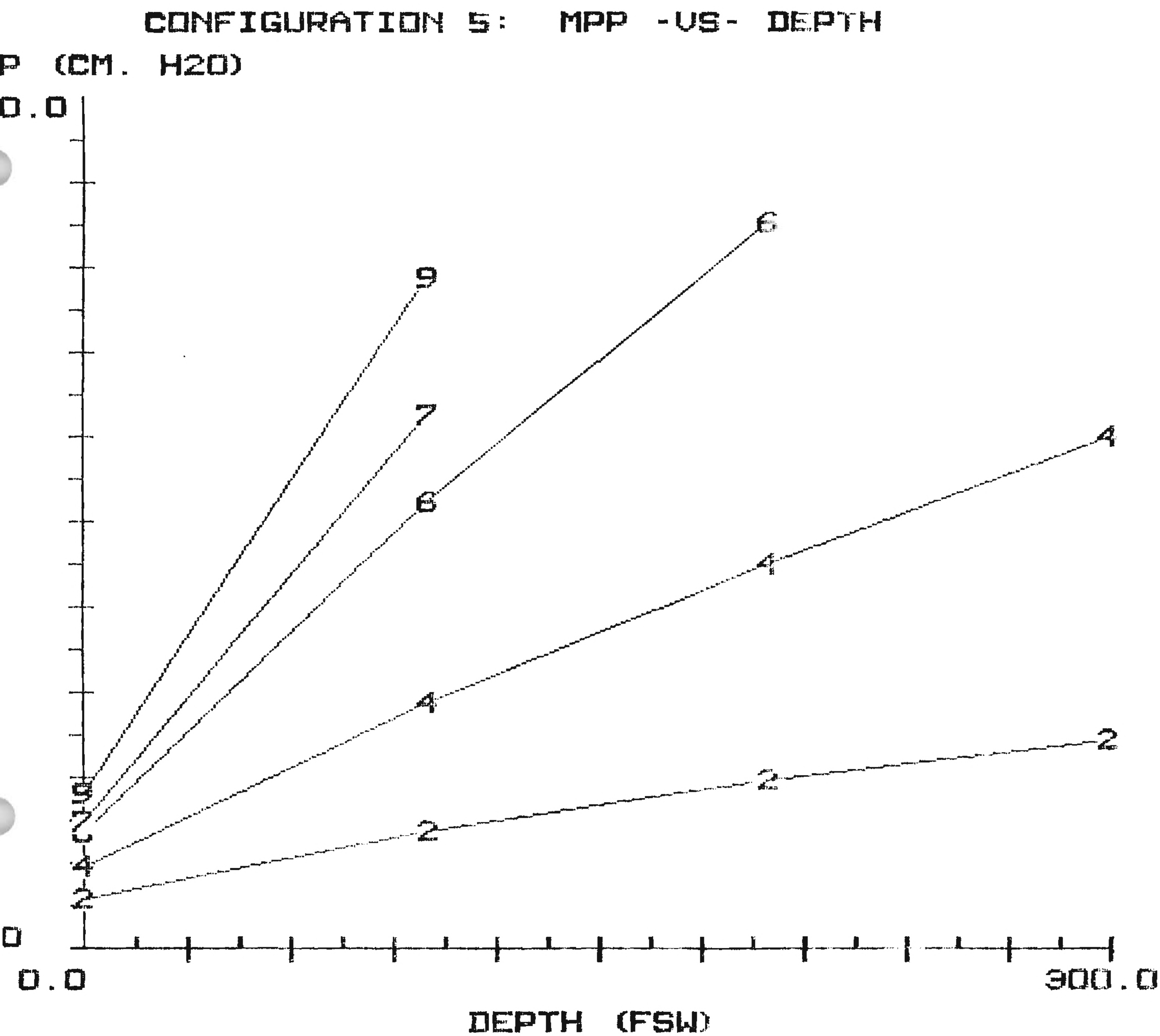


FIGURE 28:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

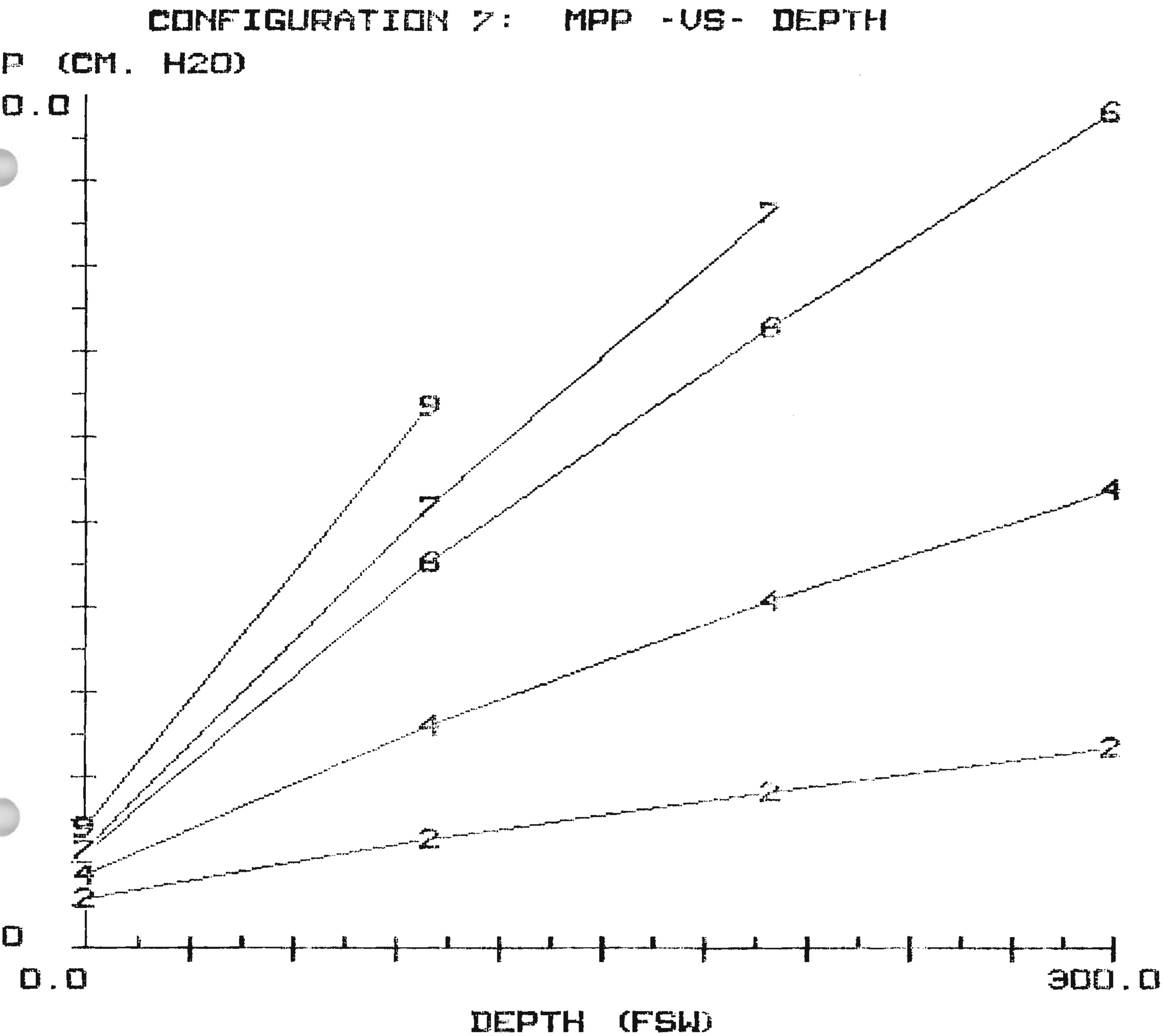


FIGURE 29:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

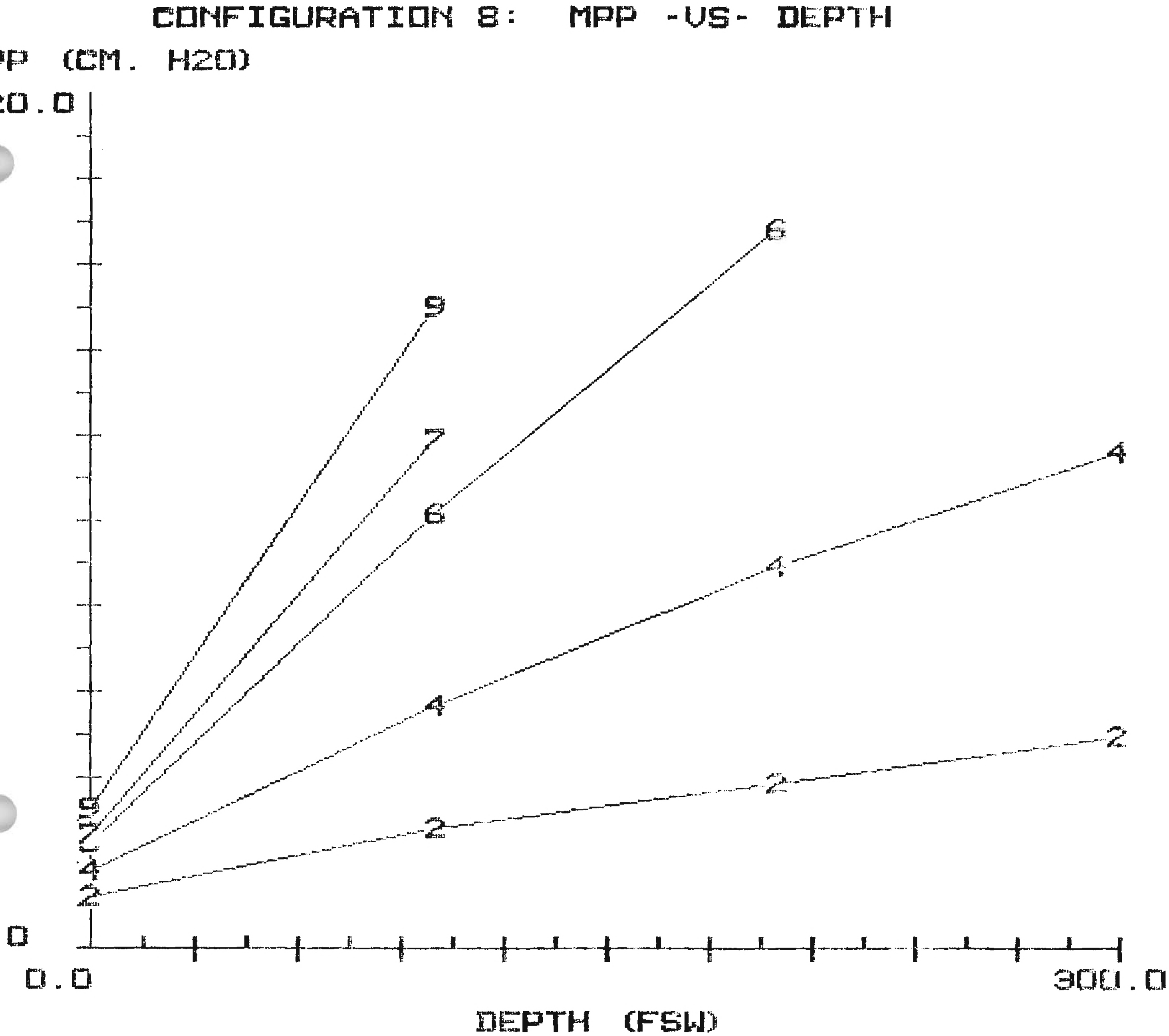


FIGURE 30:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

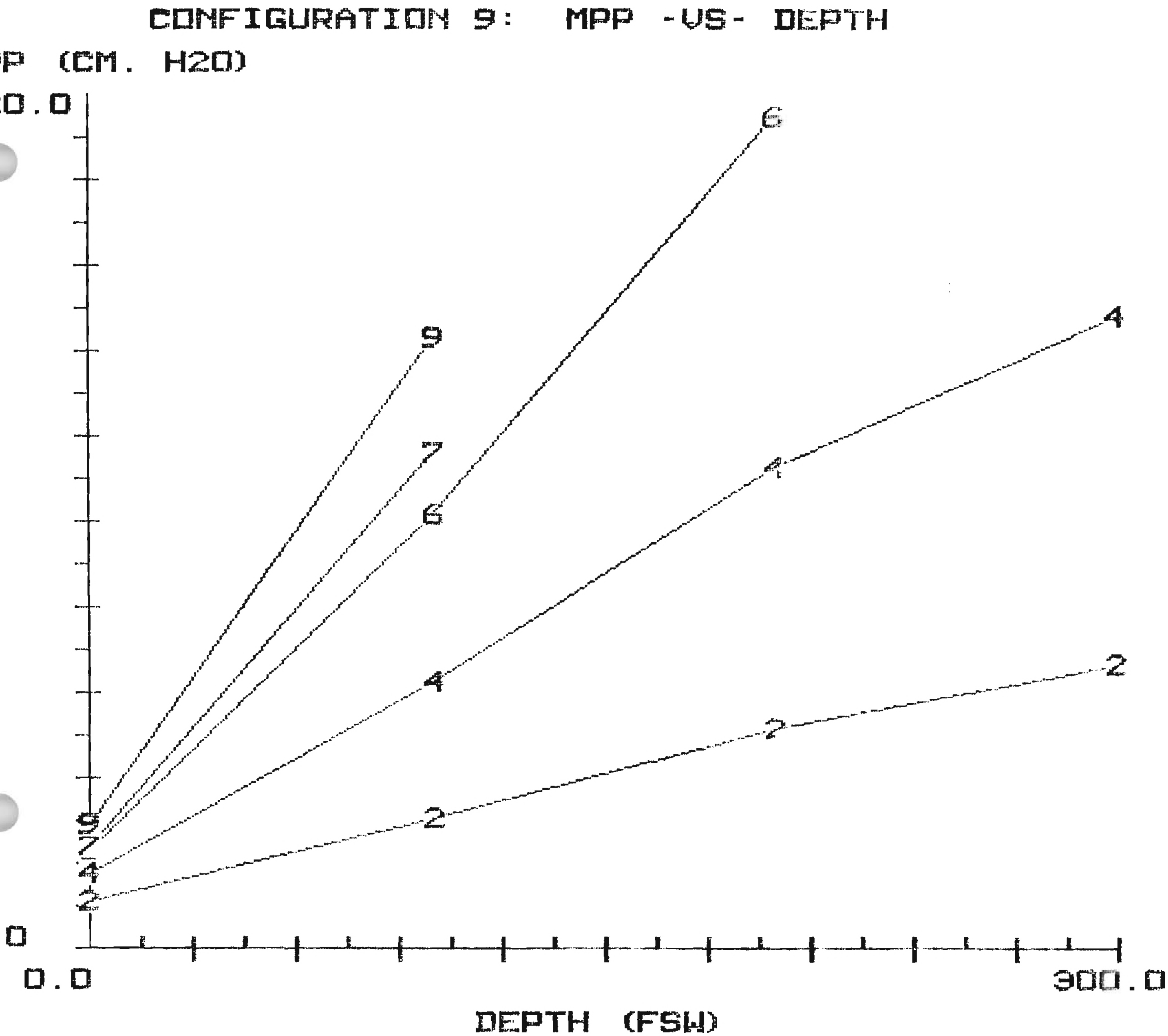


FIGURE 31:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

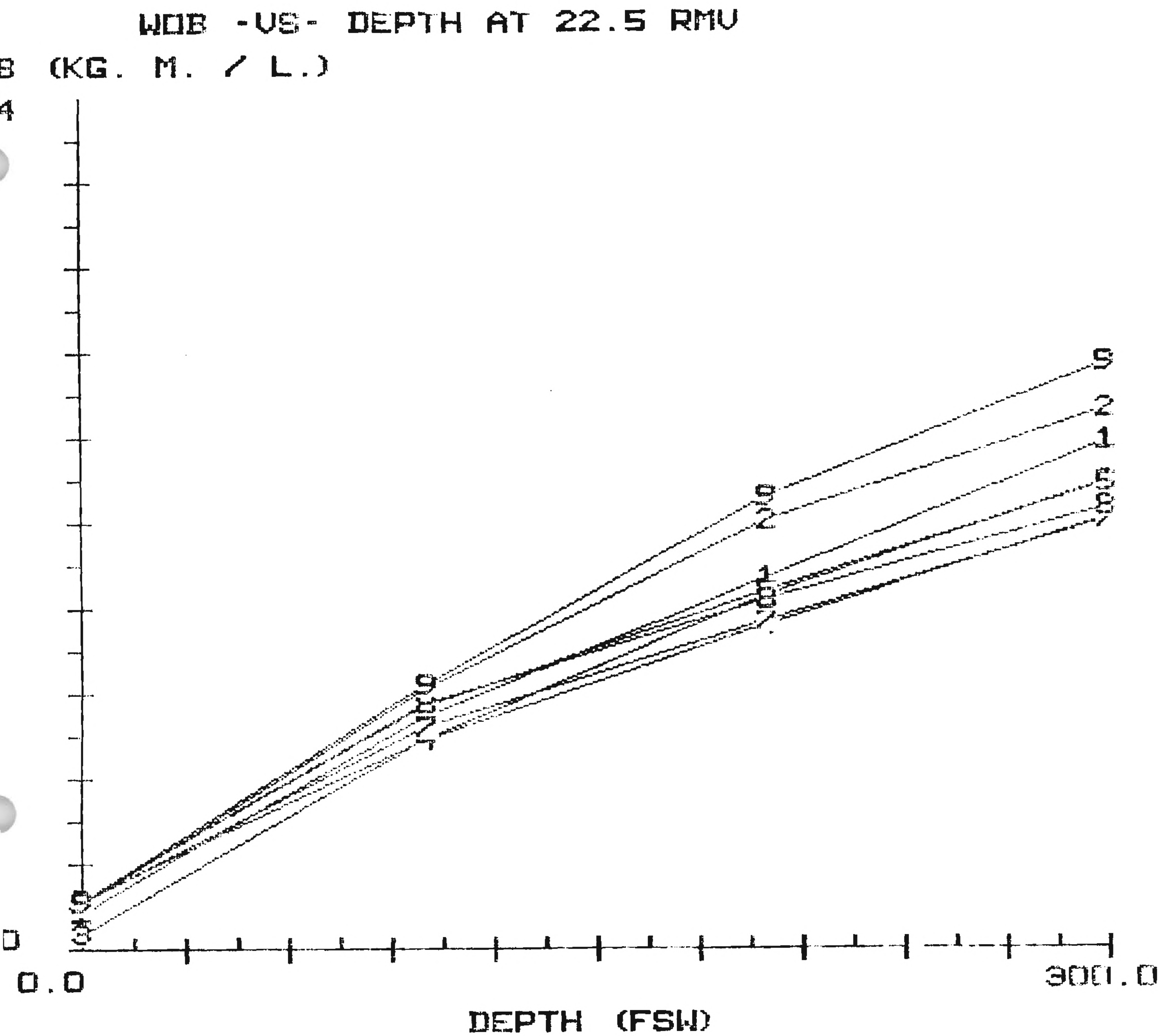


FIGURE 32:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

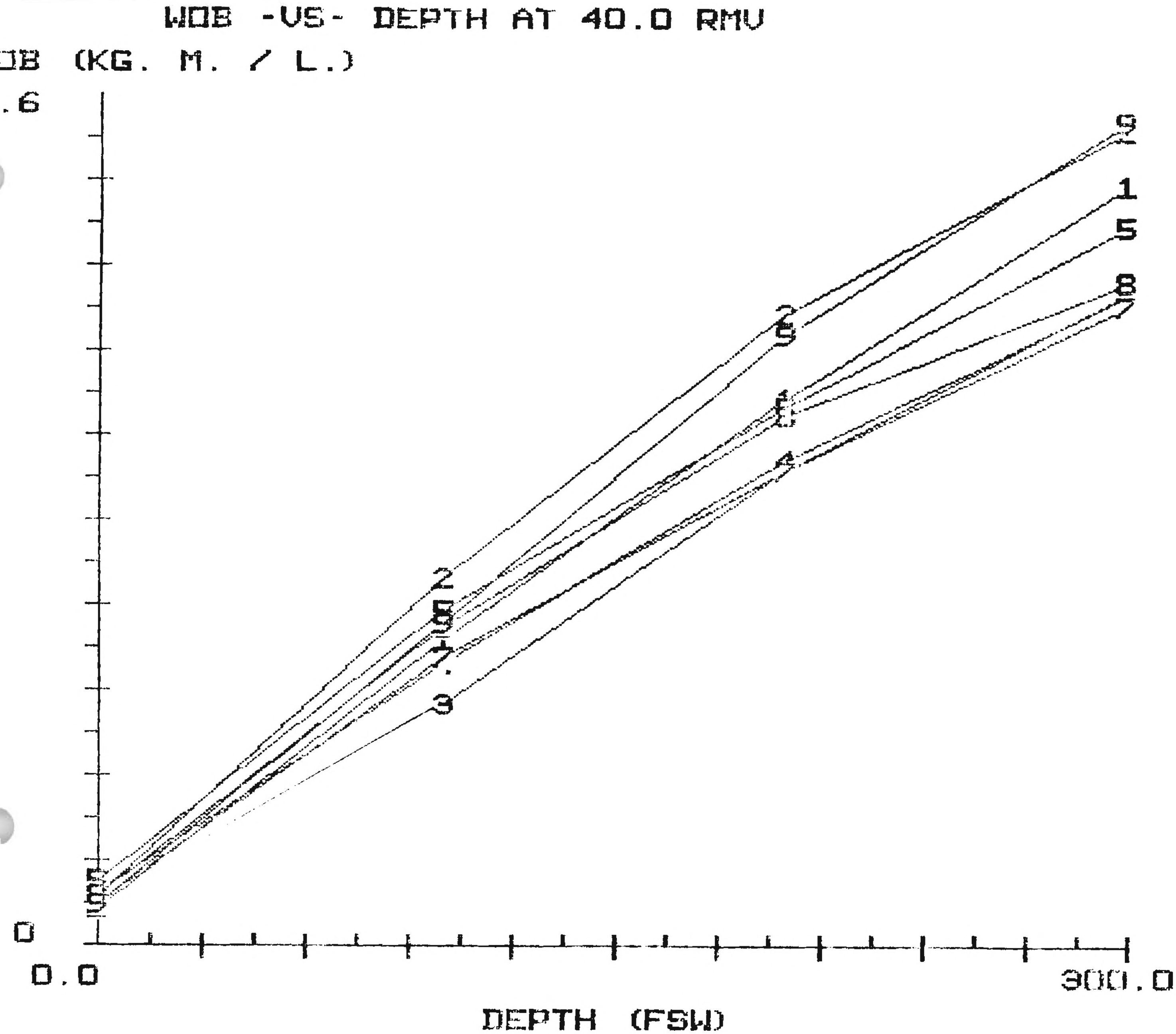


FIGURE 33:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

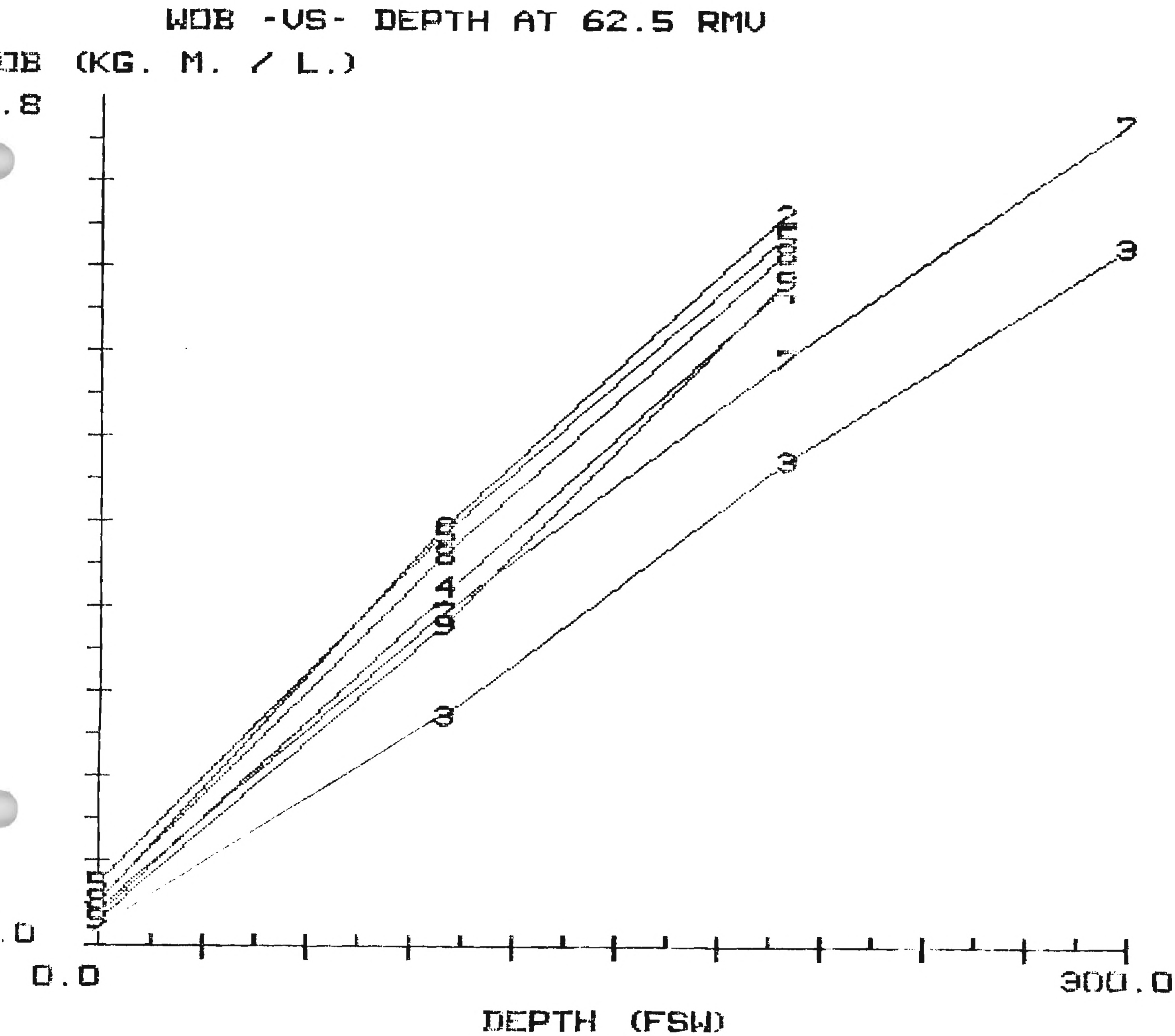


FIGURE 34:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

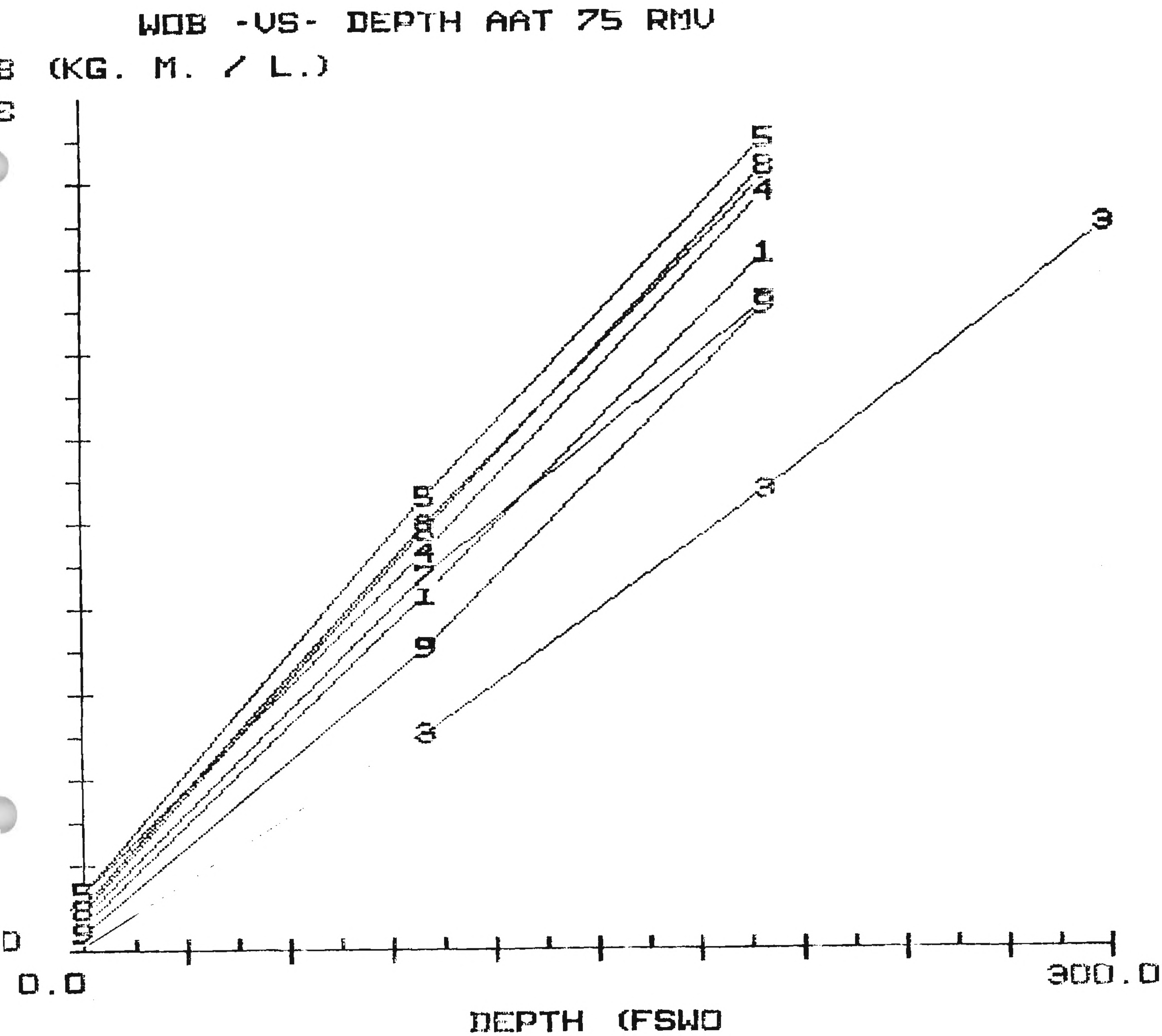


FIGURE 35:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

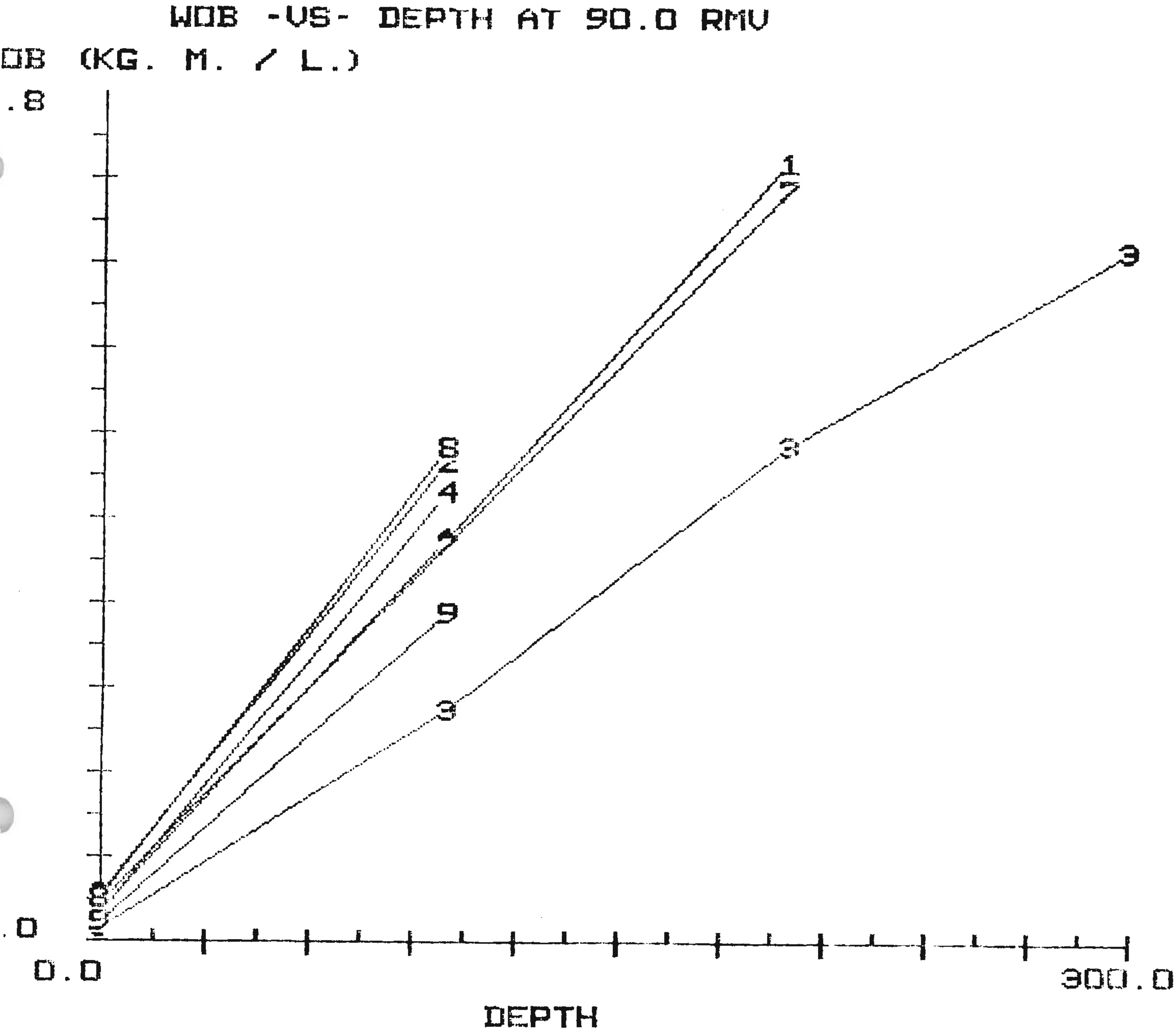


FIGURE 36:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

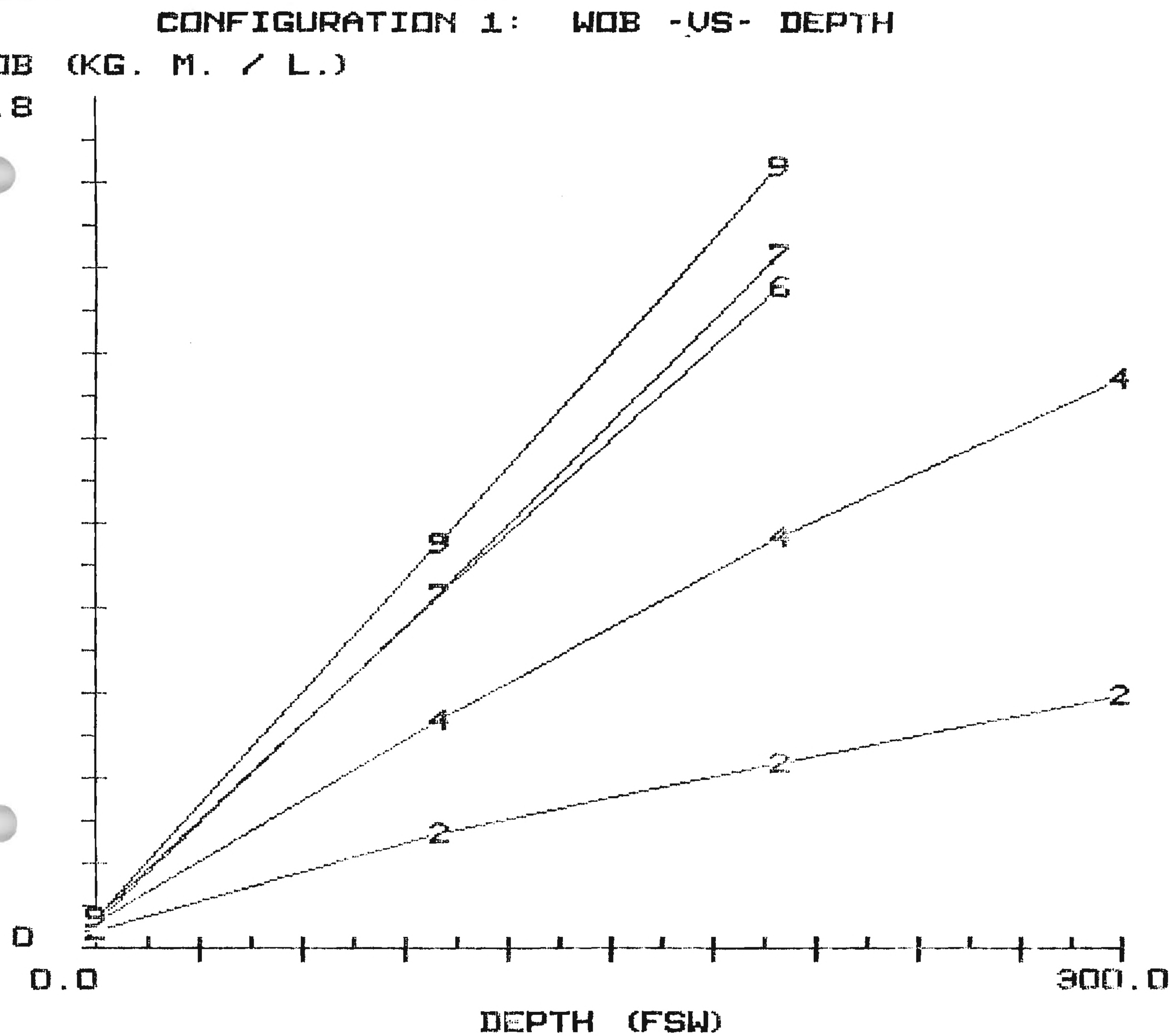


FIGURE 37:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

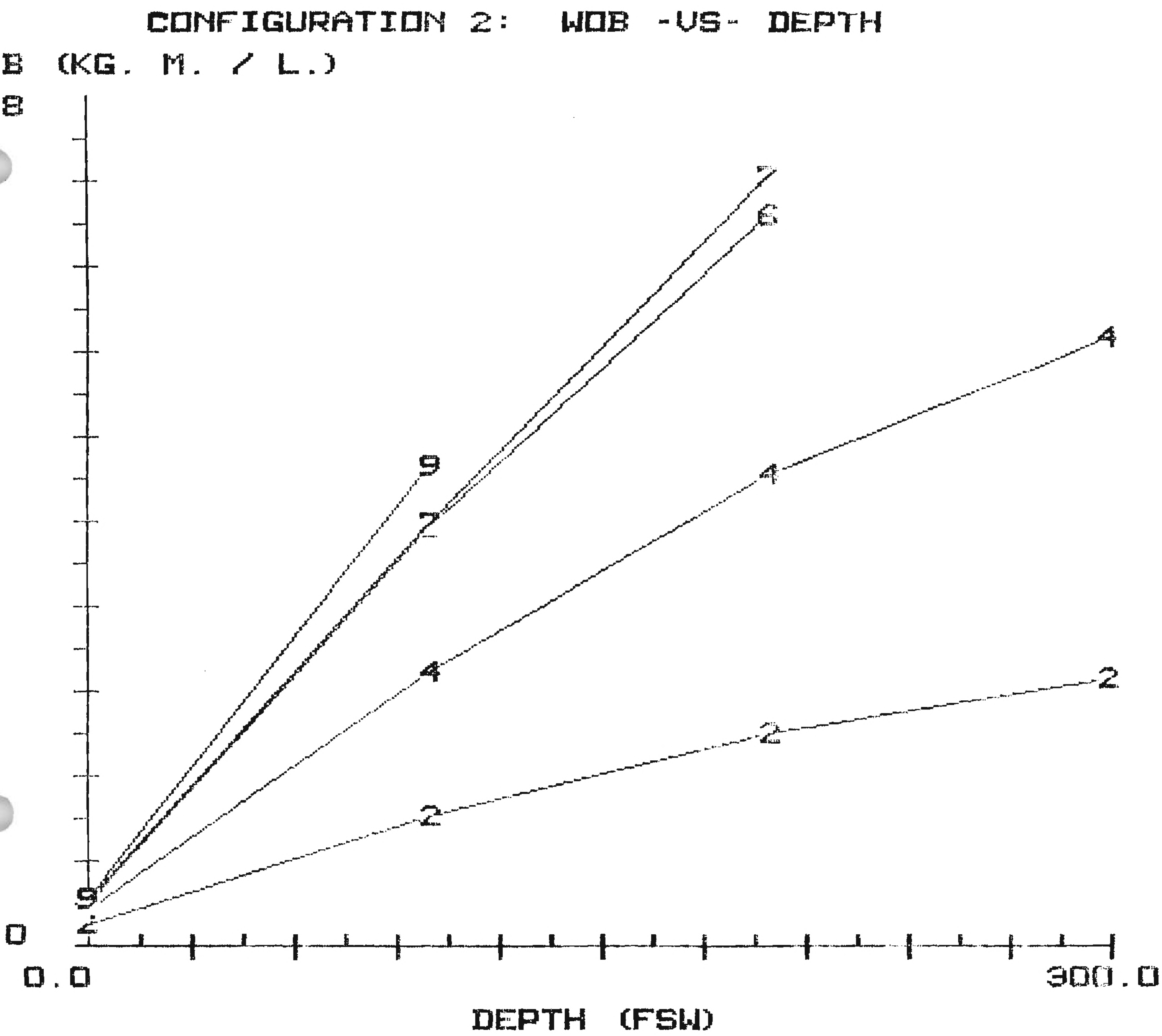


FIGURE 38:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

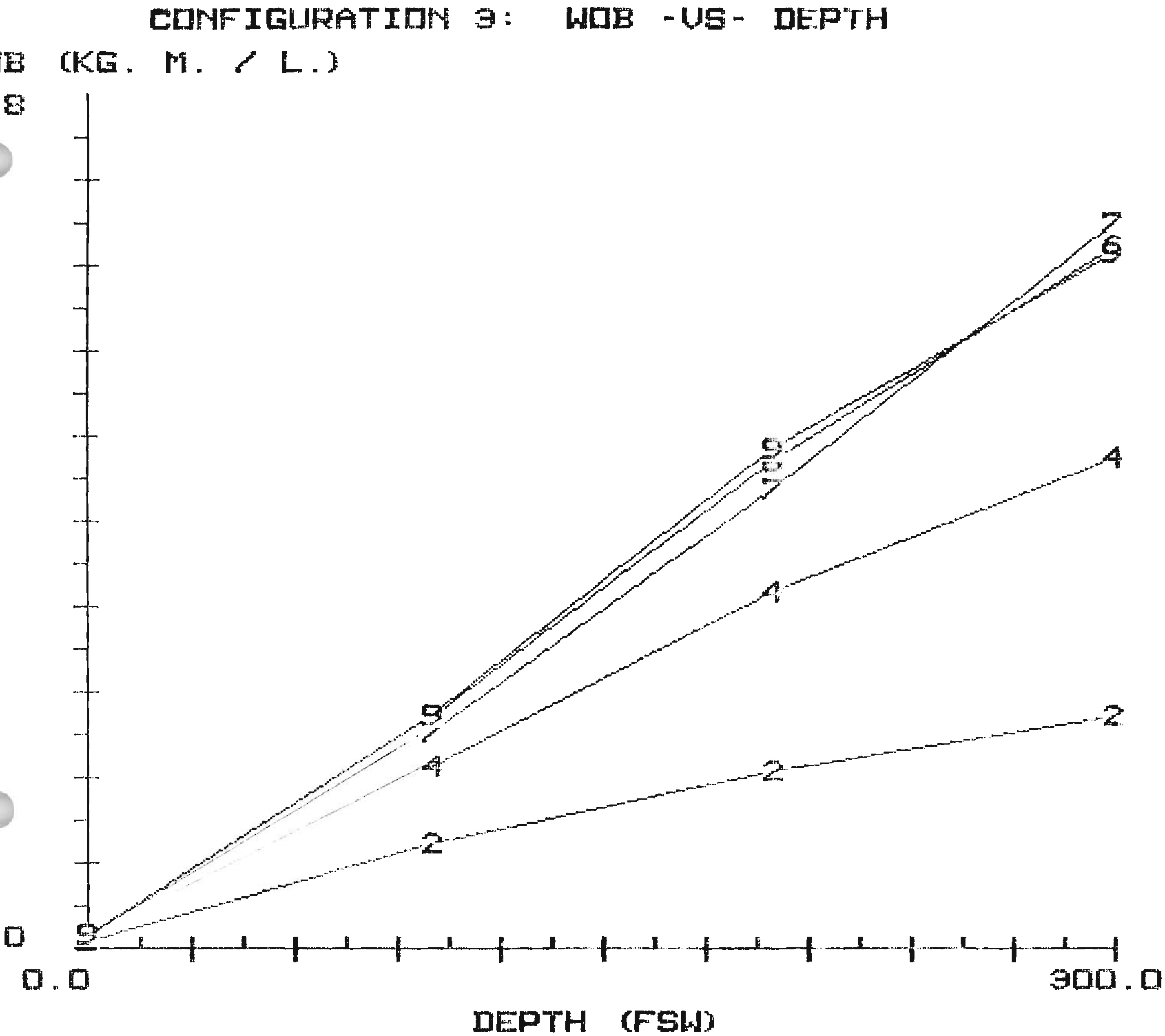


FIGURE 39:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

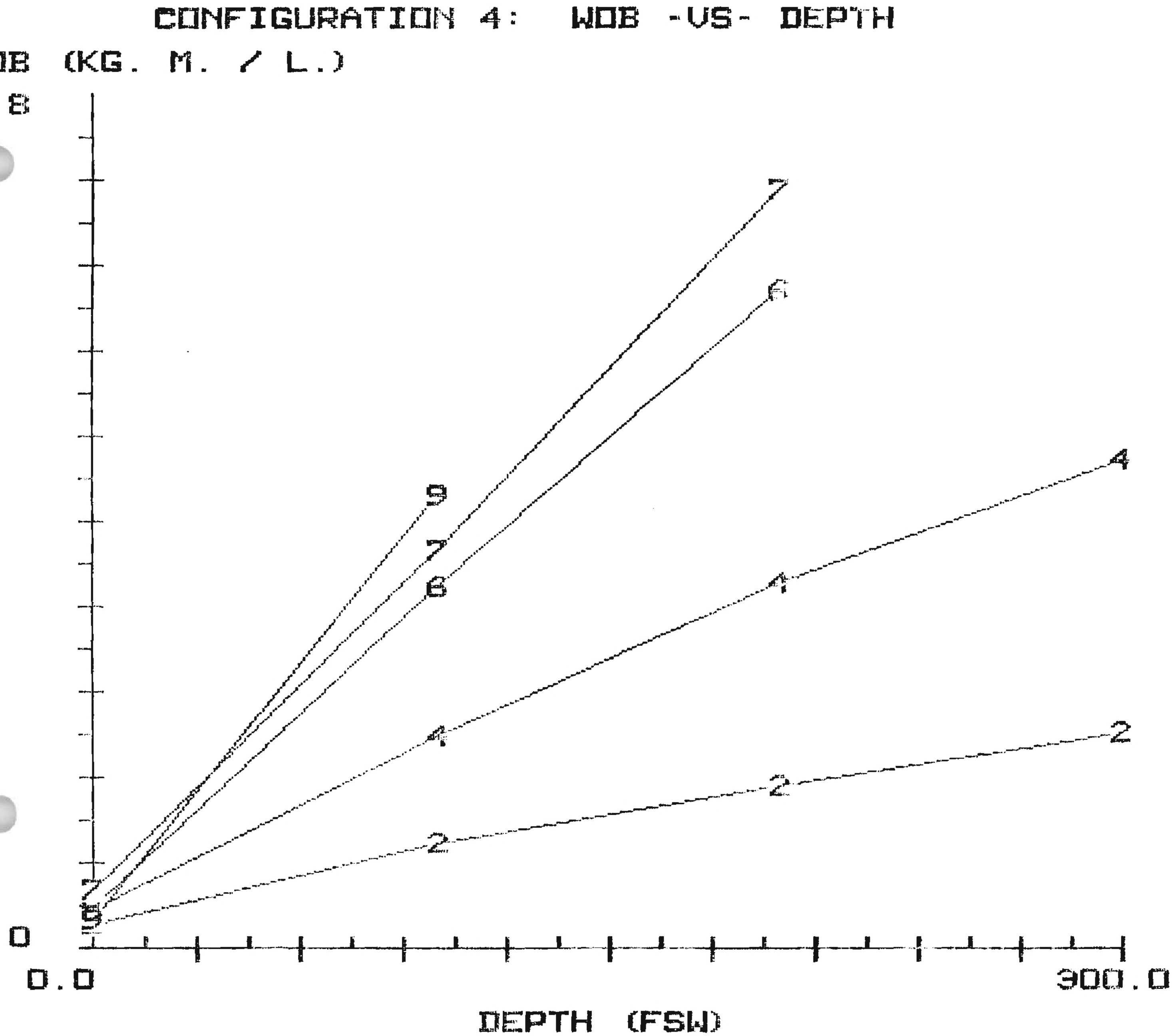


FIGURE 40:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

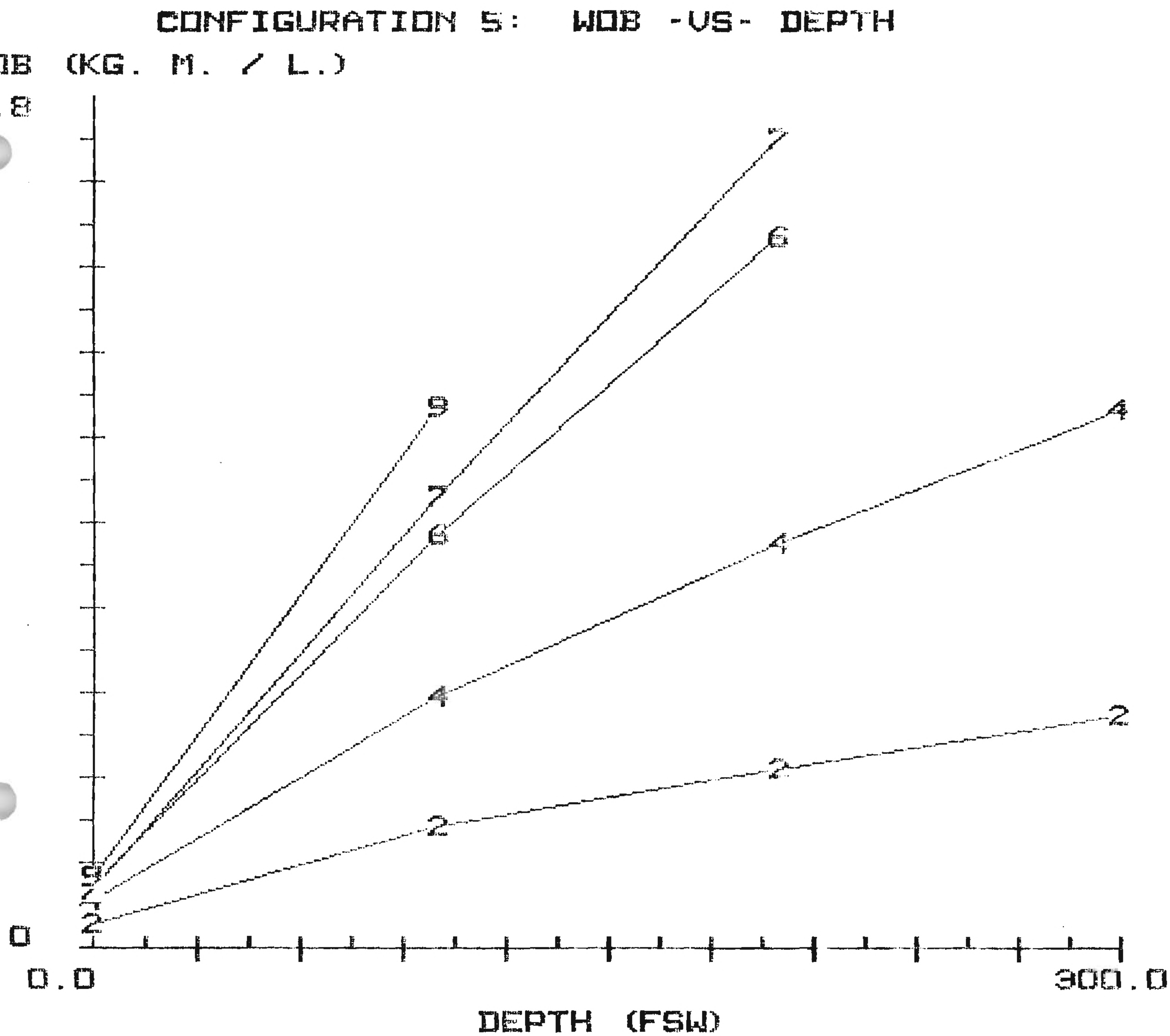


FIGURE 41:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

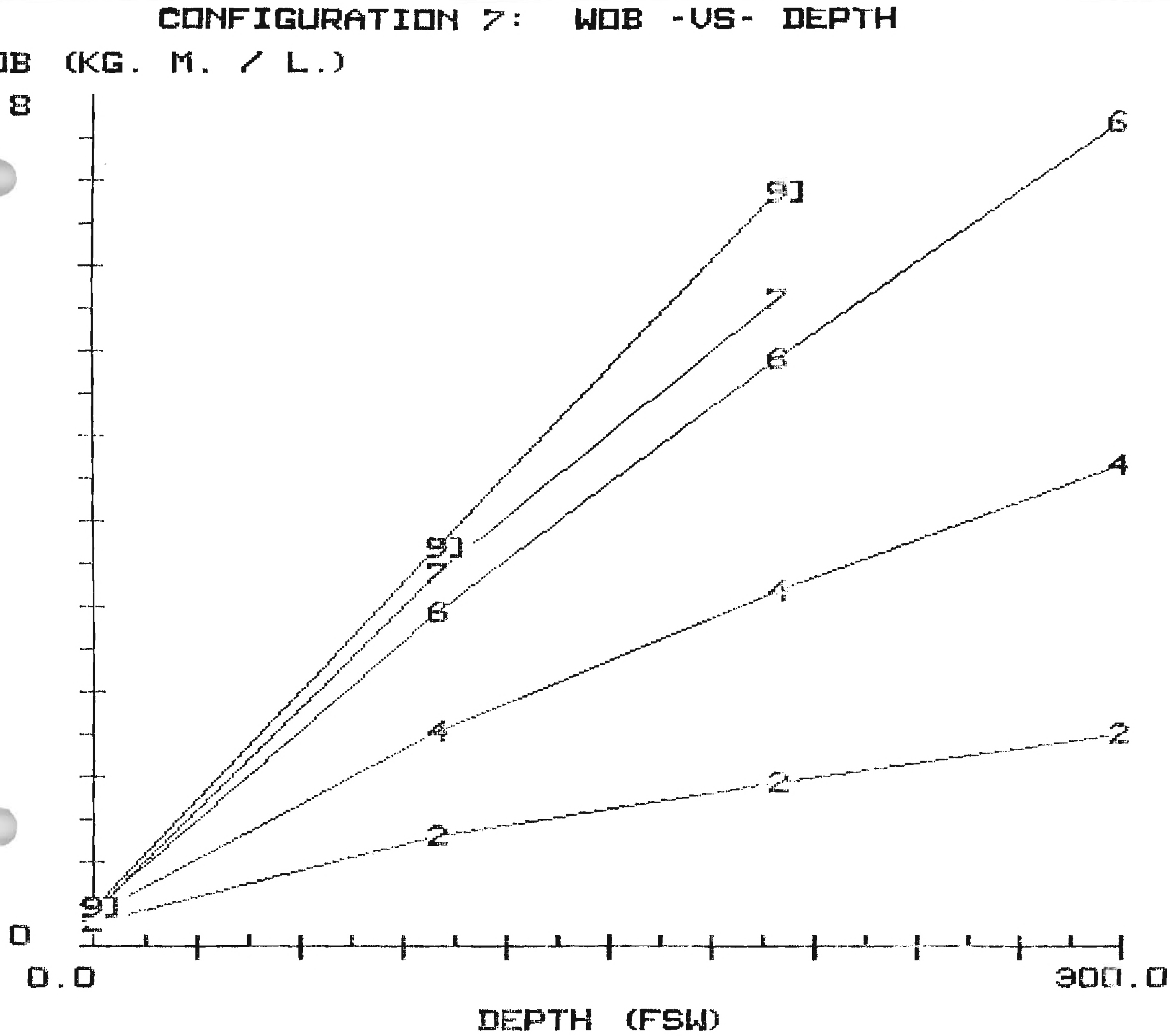


FIGURE 42:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
9 = TESTS AT 90.0 RMV.

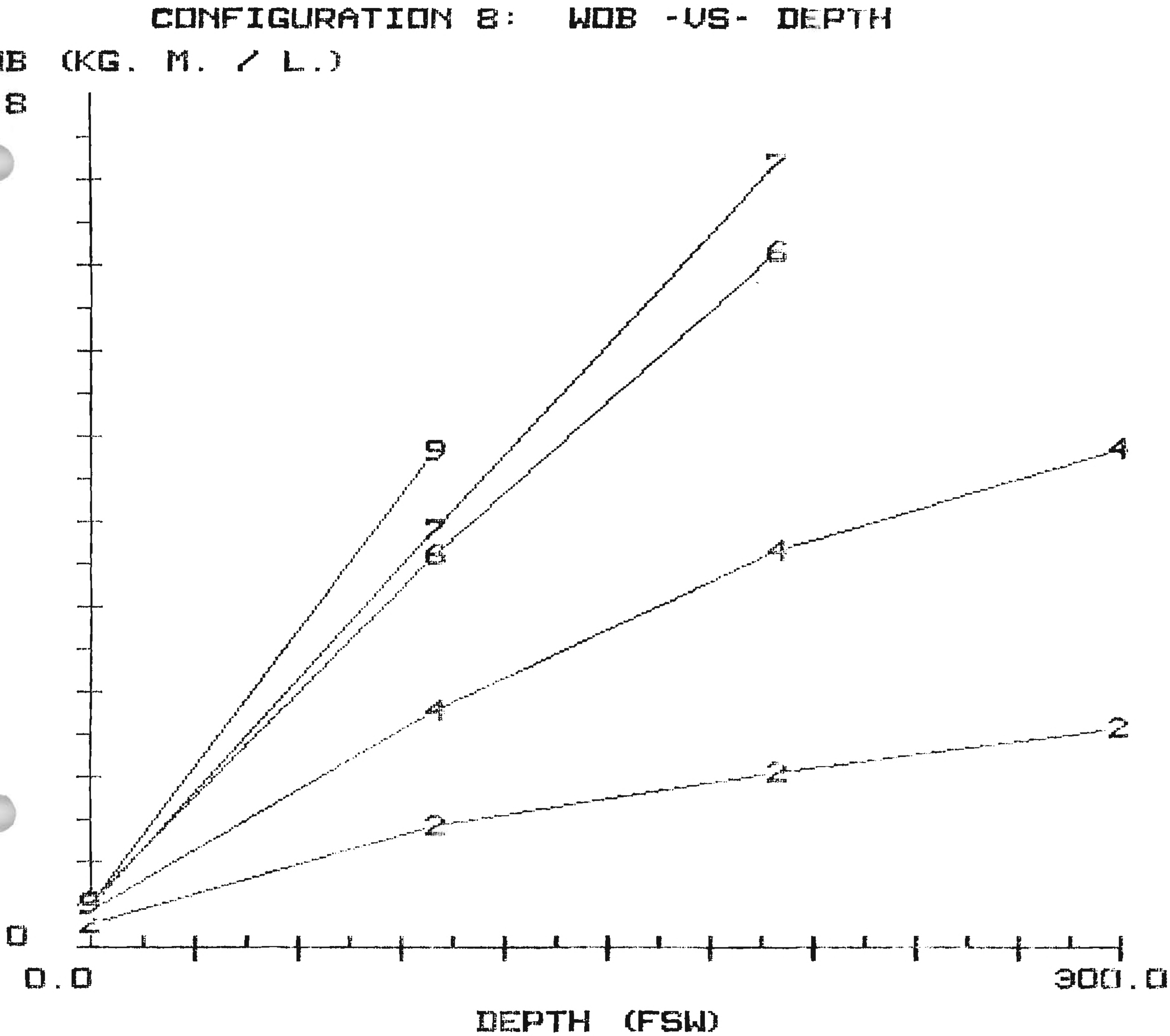


Figure 43:

1. 2 = TESTS AT 22.5 RMV.
2. 4 = TESTS AT 40.0 RMV.
3. 6 = TESTS AT 62.5 RMV.
4. 7 = TESTS AT 75.0 RMV.
5. 9 = TESTS AT 90.0 RMV.

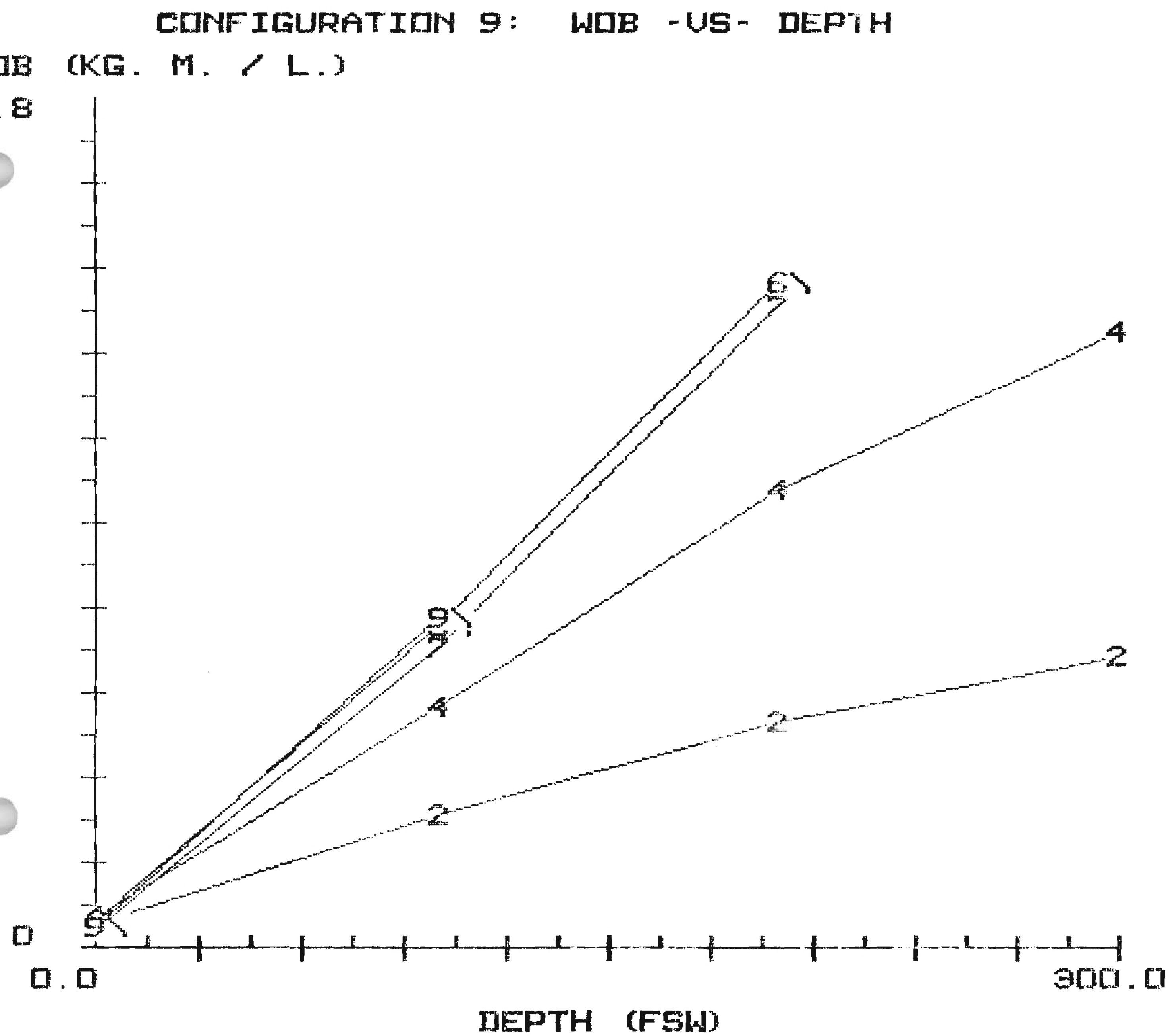


FIGURE 44:

2 = TESTS AT 22.5 RMV.
4 = TESTS AT 40.0 RMV.
6 = TESTS AT 62.5 RMV.
7 = TESTS AT 75.0 RMV.
= TESTS AT 90.0 RMV.

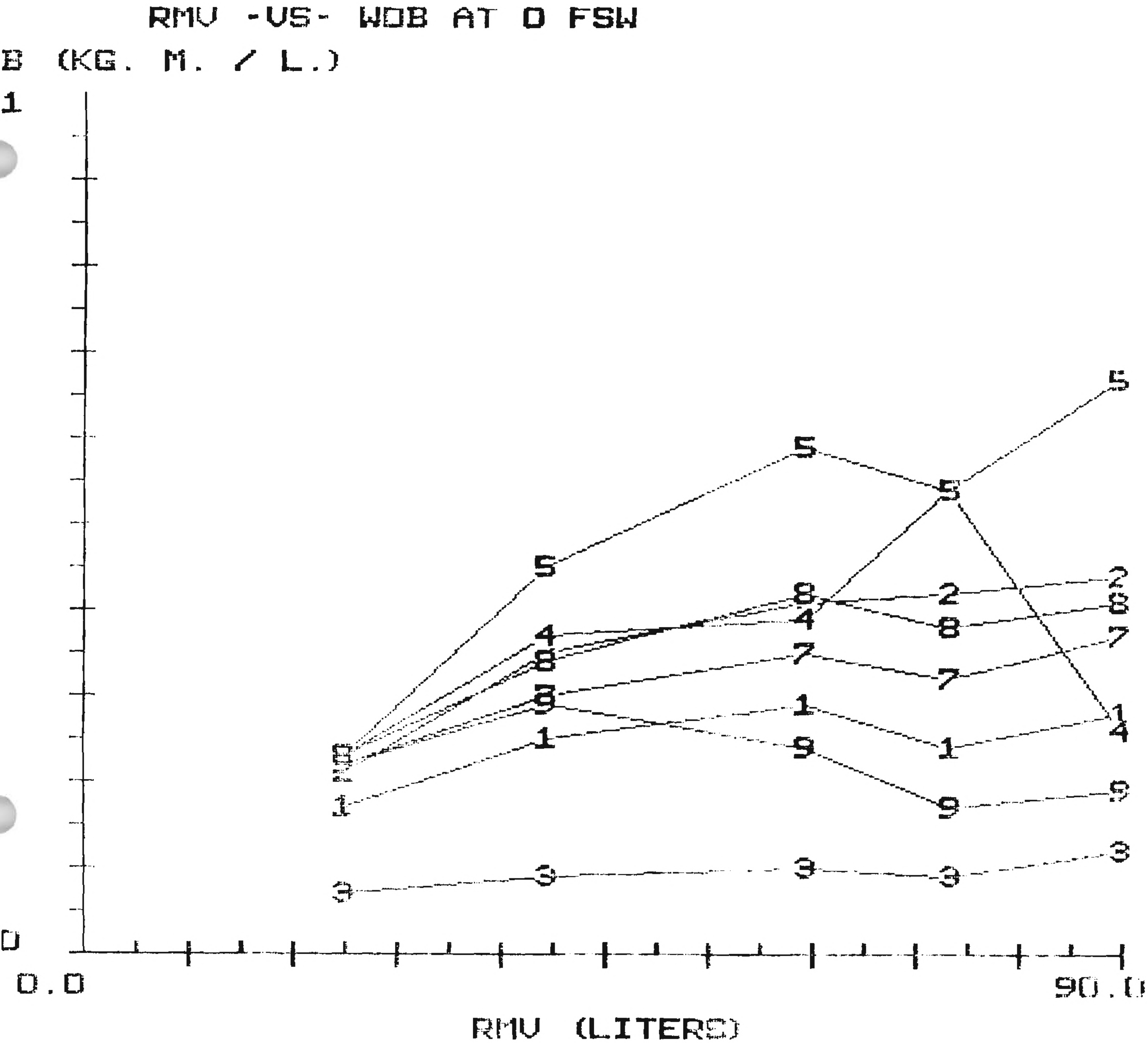


FIGURE 45:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

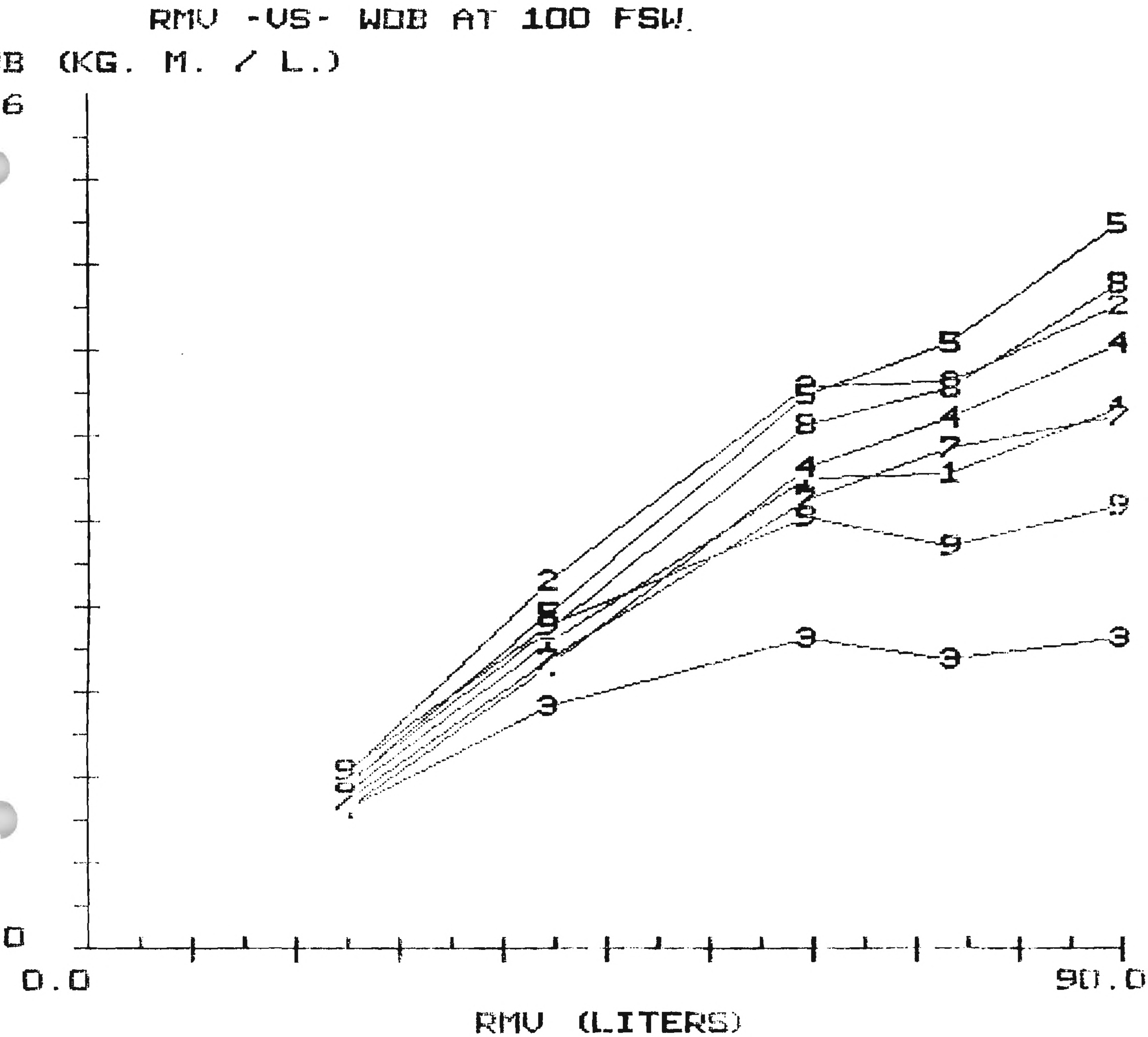


FIGURE 46:

1 = TESTS ON CONFIG. 1
2 = TESTS ON CONFIG. 2.
3 = TESTS ON CONFIG. 3.
4 = TESTS ON CONFIG. 4.
5 = TESTS ON CONFIG. 5.
7 = TESTS ON CONFIG. 7.
8 = TESTS ON CONFIG. 8.
9 = TESTS ON CONFIG. 9.

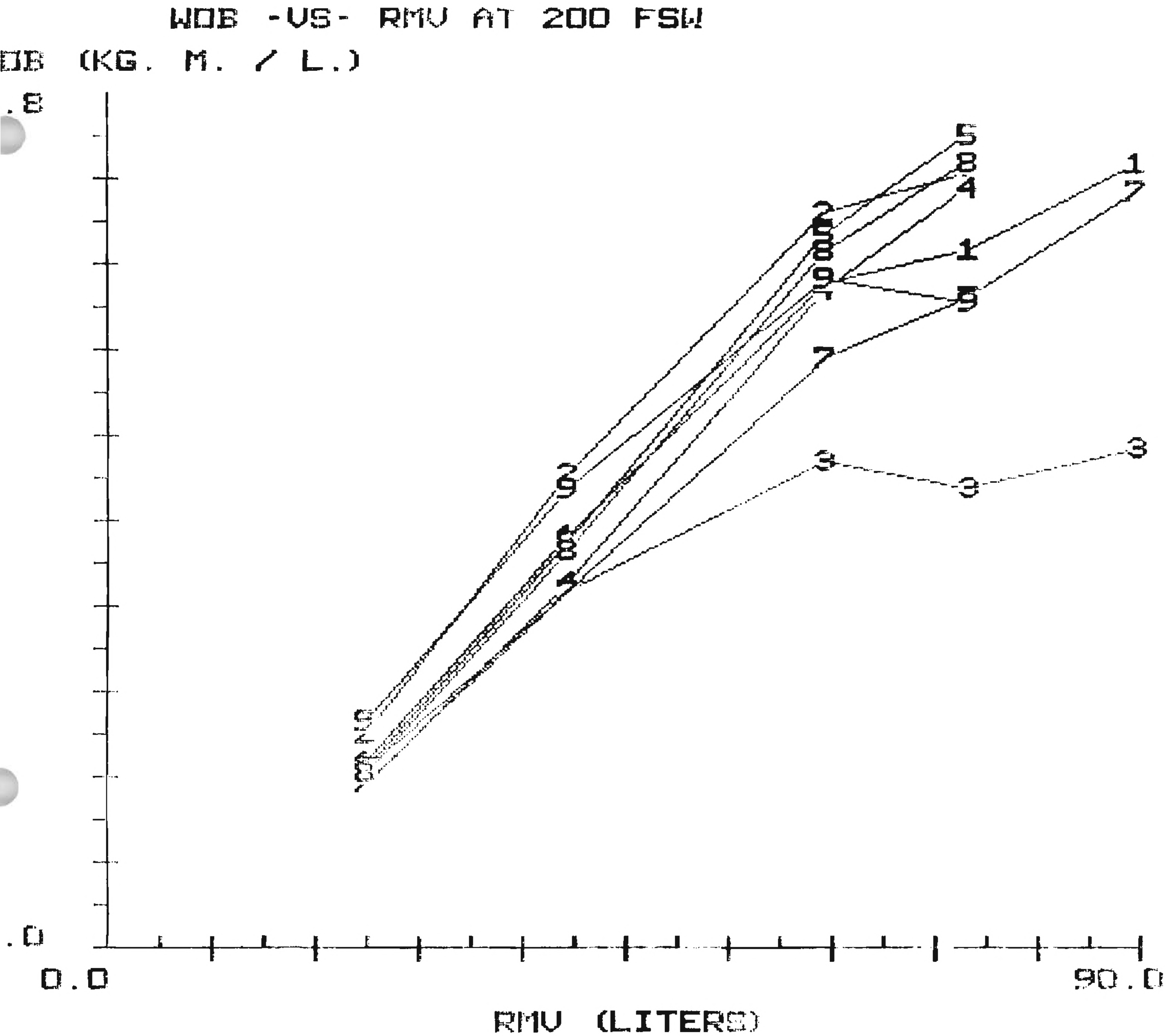


FIGURE 47:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

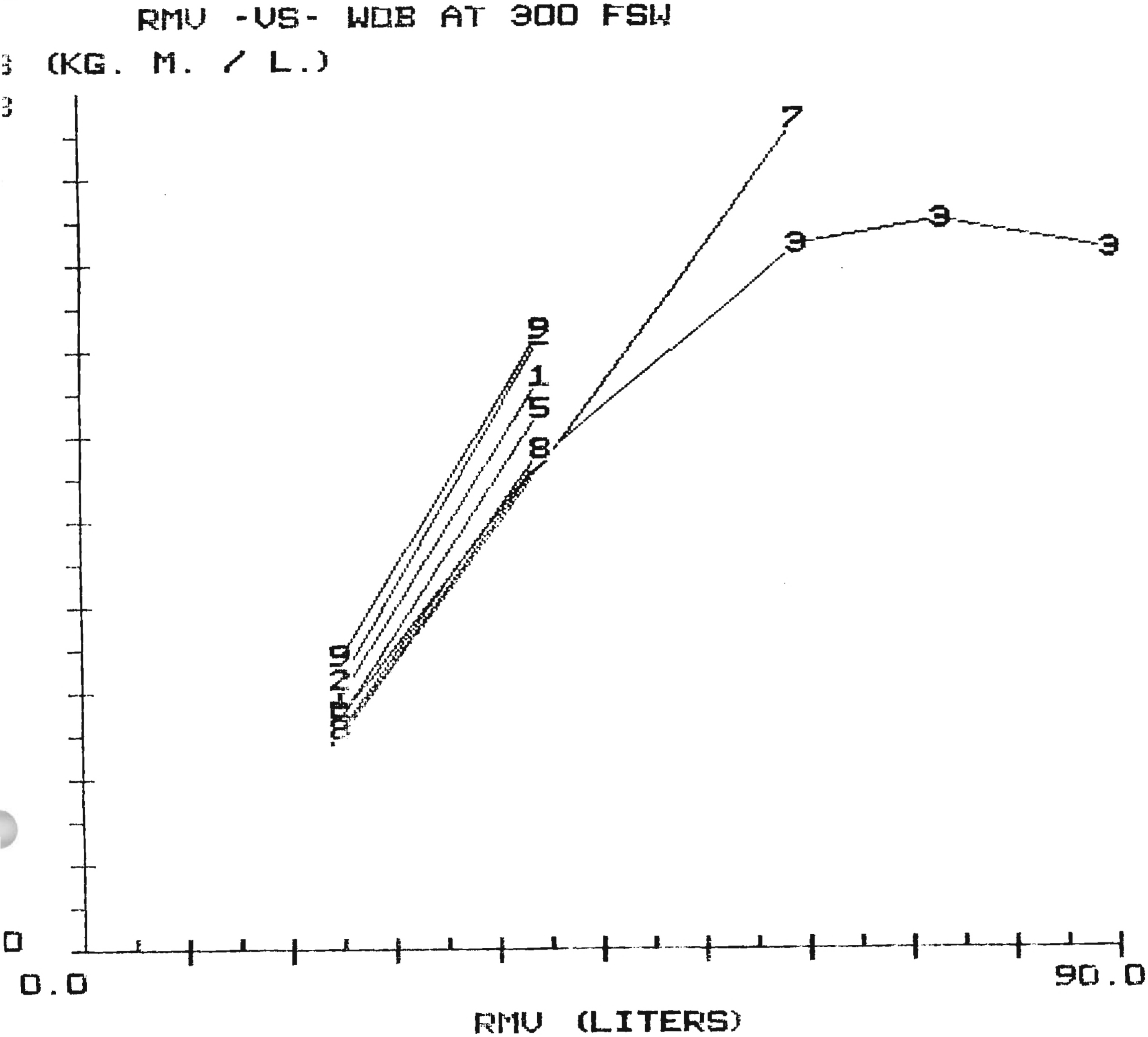


FIGURE 48:

1. 1 = TESTS ON CONFIG. 1.
2. 2 = TESTS ON CONFIG. 2.
3. 3 = TESTS ON CONFIG. 3.
4. 4 = TESTS ON CONFIG. 4.
5. 5 = TESTS ON CONFIG. 5.
6. 7 = TESTS ON CONFIG. 7.
7. 8 = TESTS ON CONFIG. 8.
8. 9 = TESTS ON CONFIG. 9.

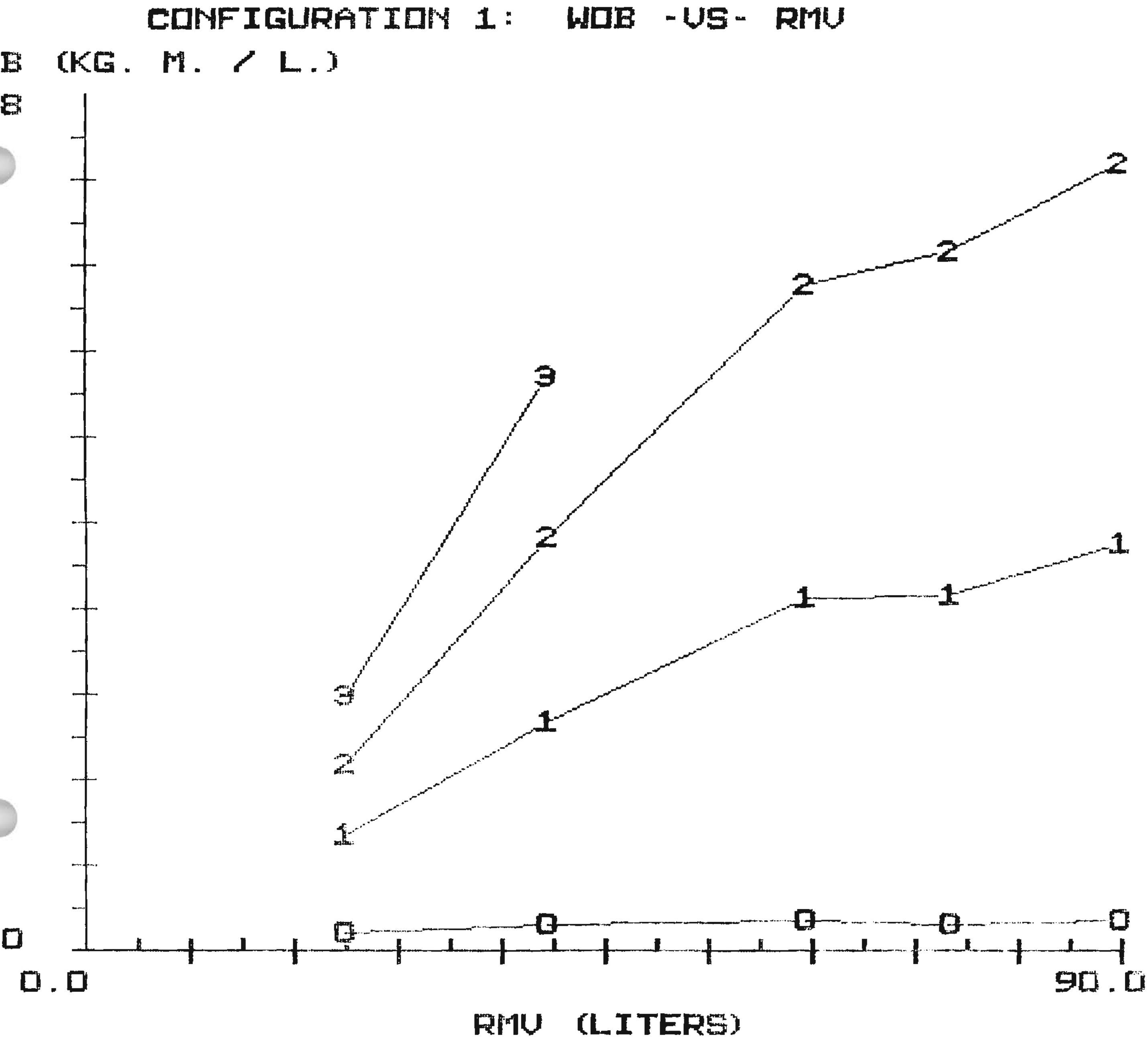


FIGURE 49:

0 = TESTS AT 0 FSW
1 = TESTS AT 100 FSW.
2 = TESTS AT 200 FSW.
3 = TESTS AT 300 FSW.

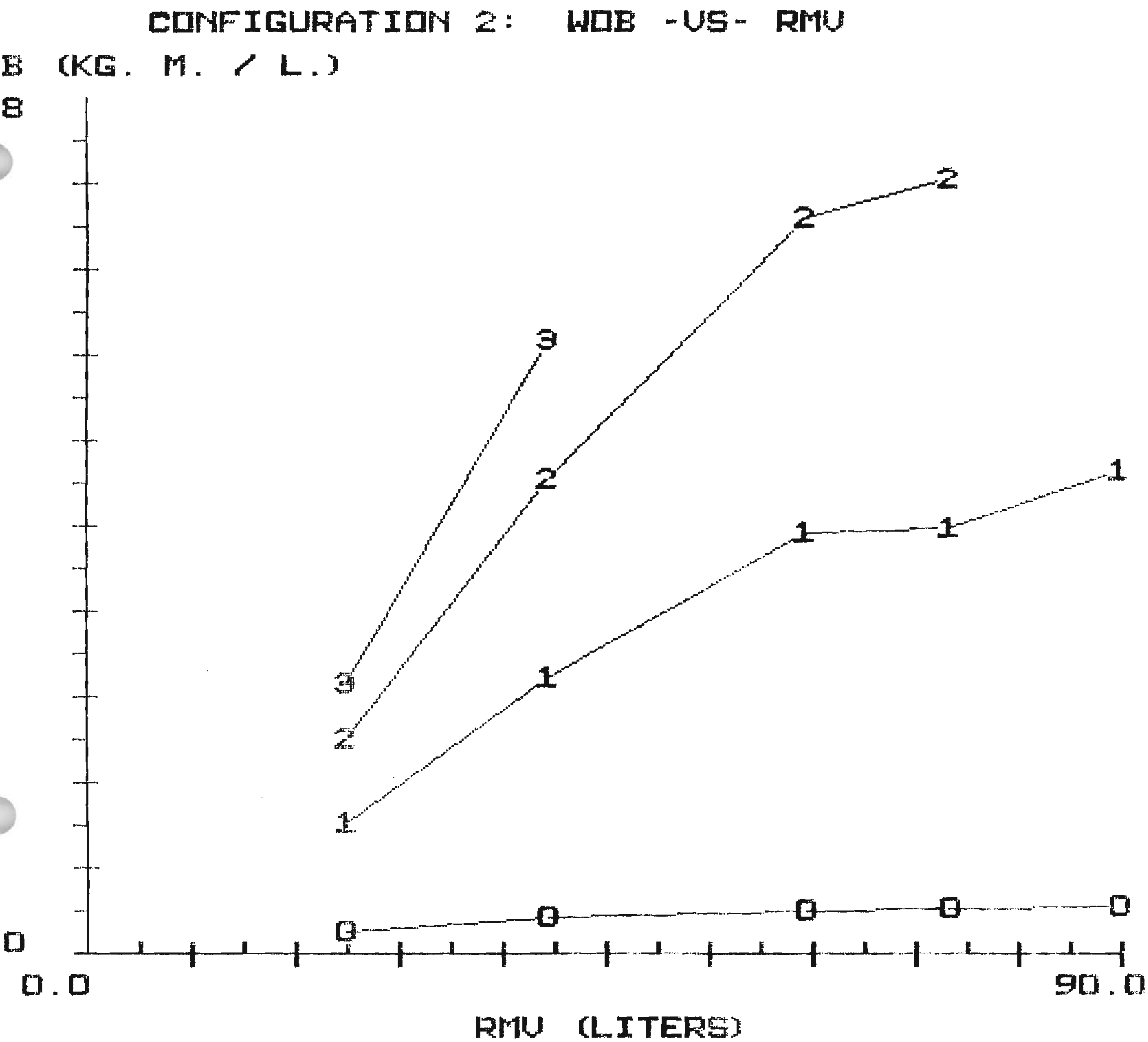


FIGURE 50:

0 = TESTS AT 0 FSW.
1 = TESTS AT 100 FSW.
2 = TESTS AT 200 FSW.
3 = TESTS AT 300 FSW.

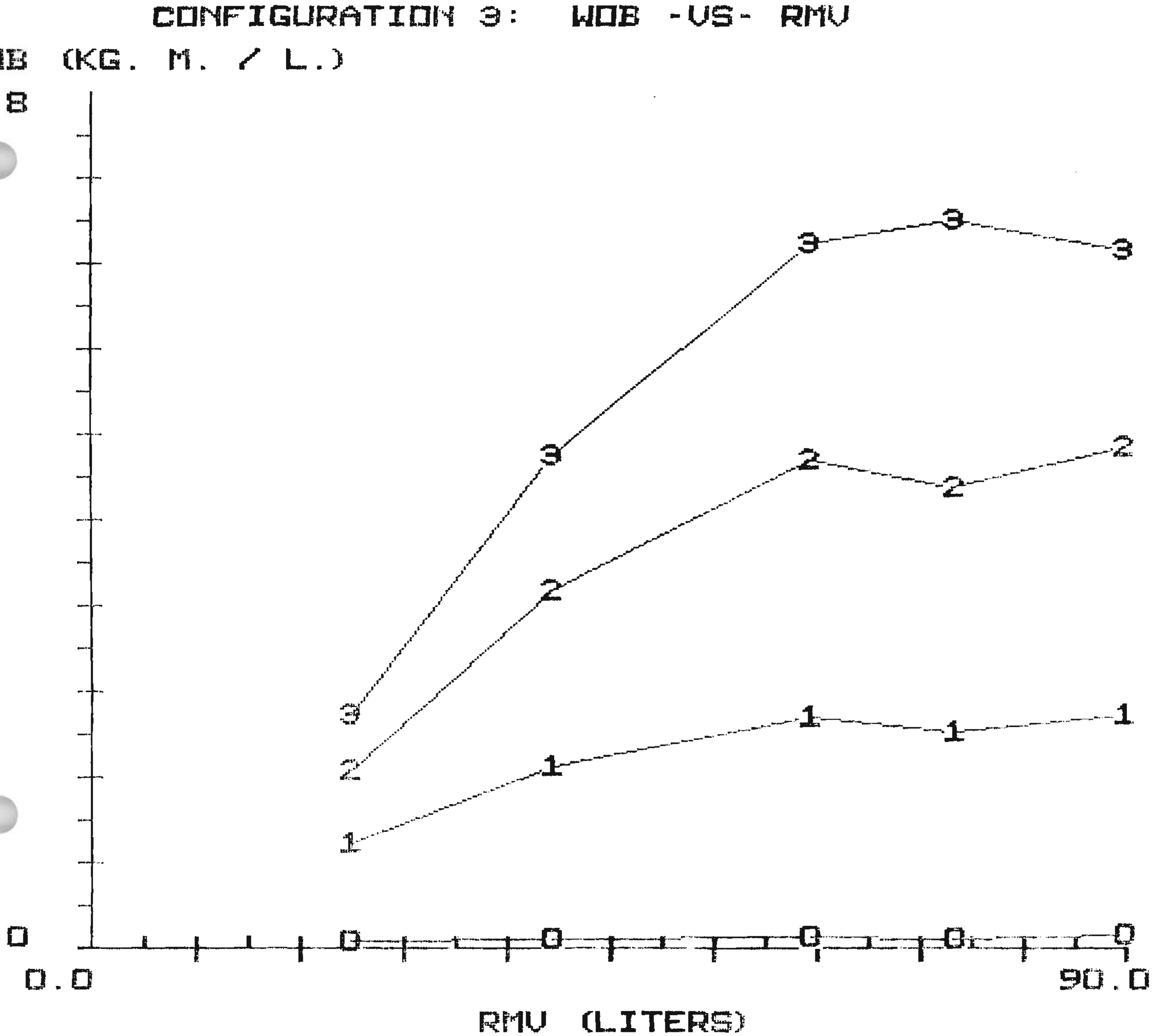


FIGURE 51:

0 = TESTS AT 0 FSW.
1 = TESTS AT 100 FSW.
2 = TESTS AT 200 FSW.
3 = TESTS AT 300 FSW.

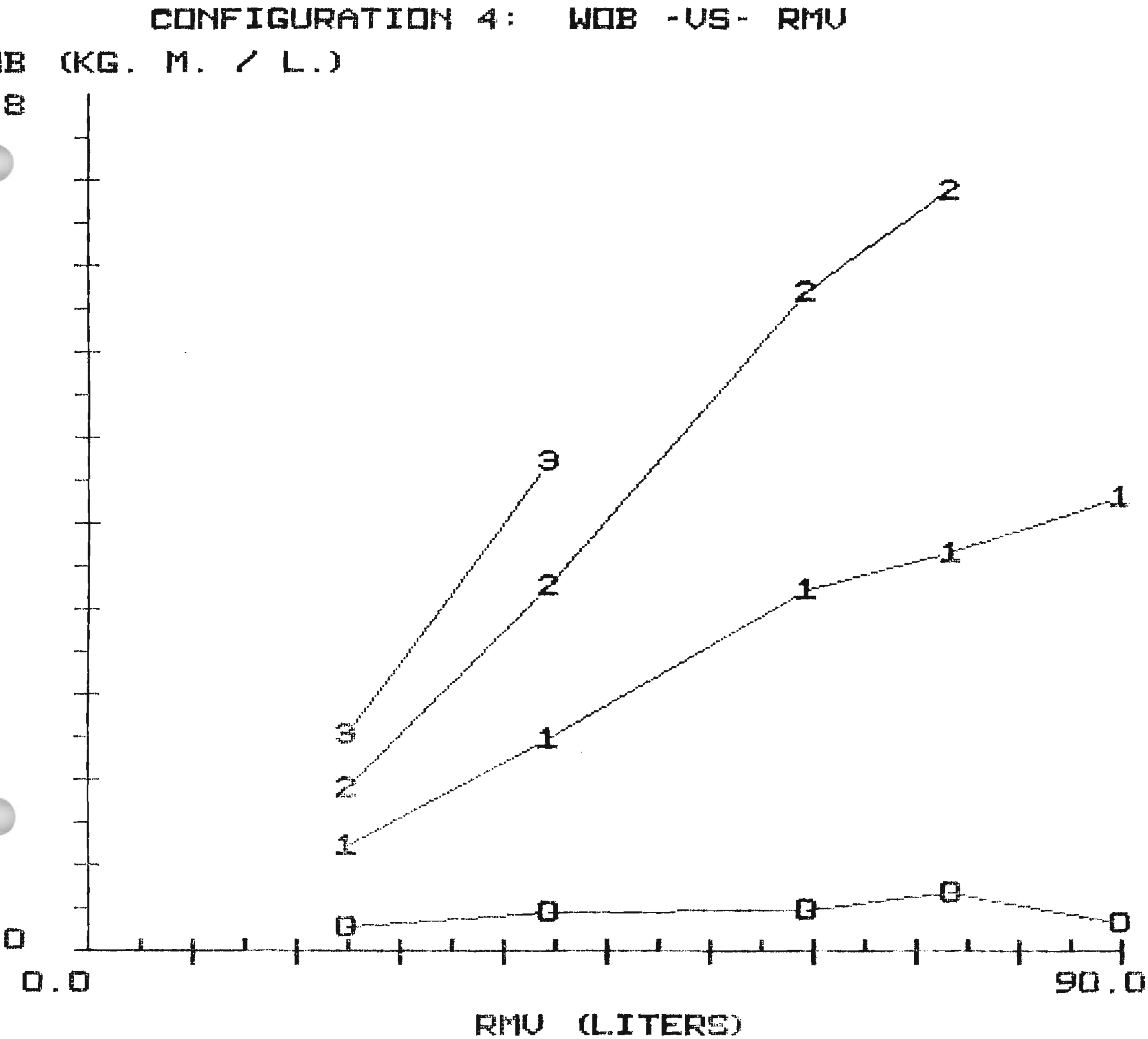


FIGURE 52:

0 = TESTS AT 0 FSW.
1 = TESTS AT 100 FSW.
2 = TESTS AT 200 FSW.
3 = TESTS AT 300 FSW.

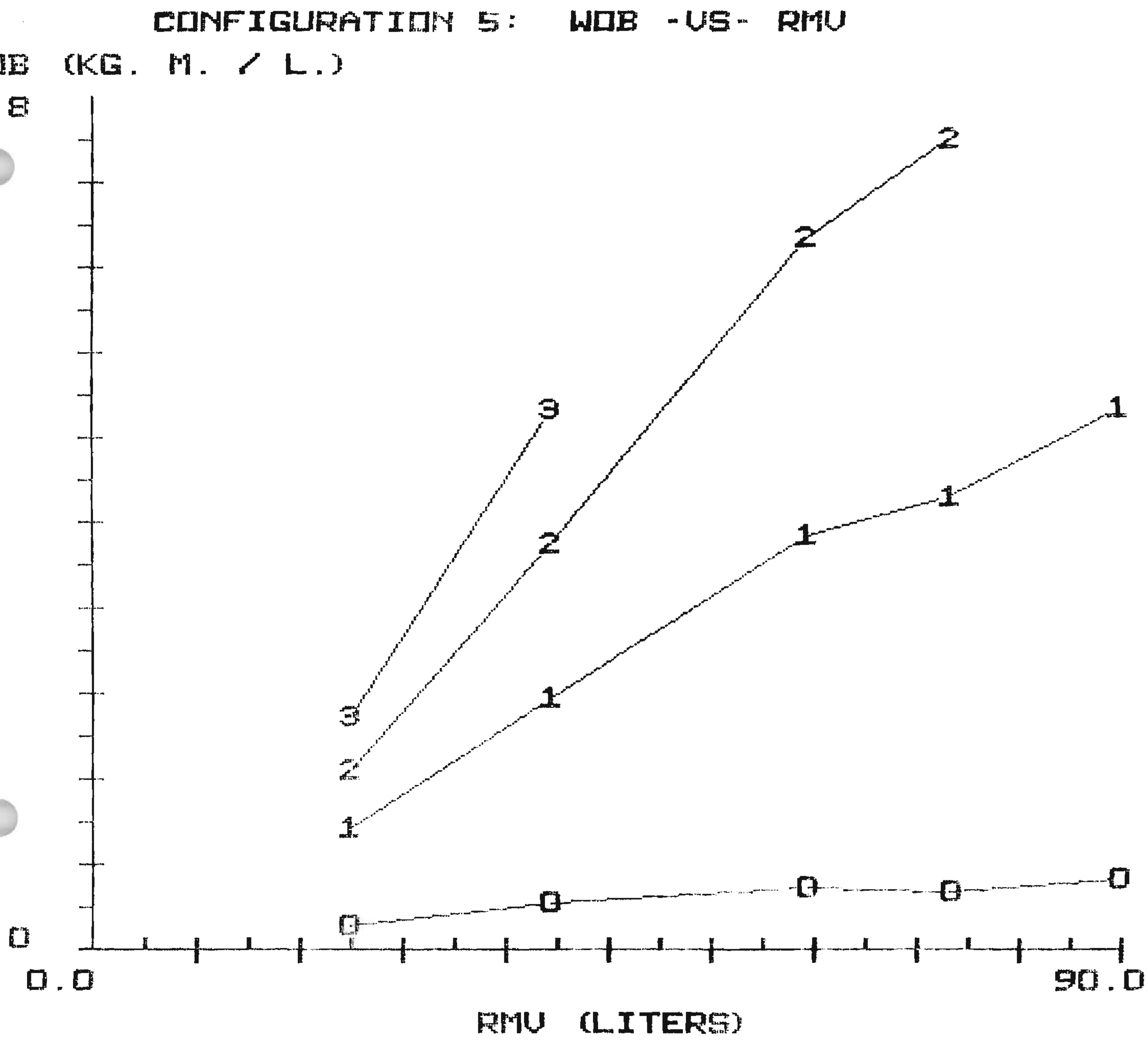


FIGURE 53:

0 = TESTS AT 0 FSW.
1 = TESTS AT 100 FSW.
2 = TESTS AT 200 FSW.
3 = TESTS AT 300 FSW.

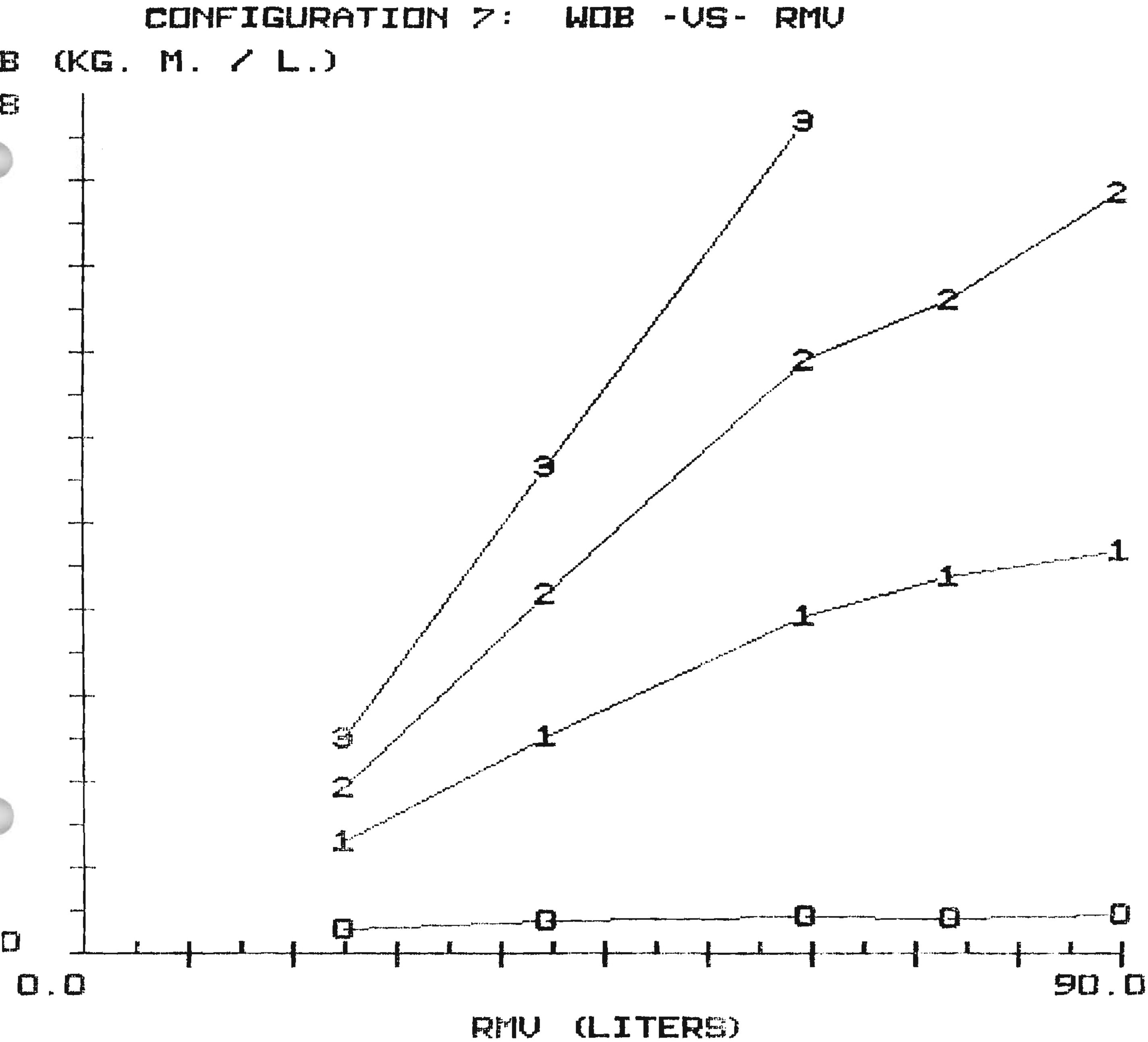


FIGURE 54:

0 = TESTS AT 0 FSW.
1 = TESTS AT 100 FSW.
2 = TESTS AT 200 FSW.
3 = TESTS AT 300 FSW.

CONFIGURATION 8: WOB -VS- RMV

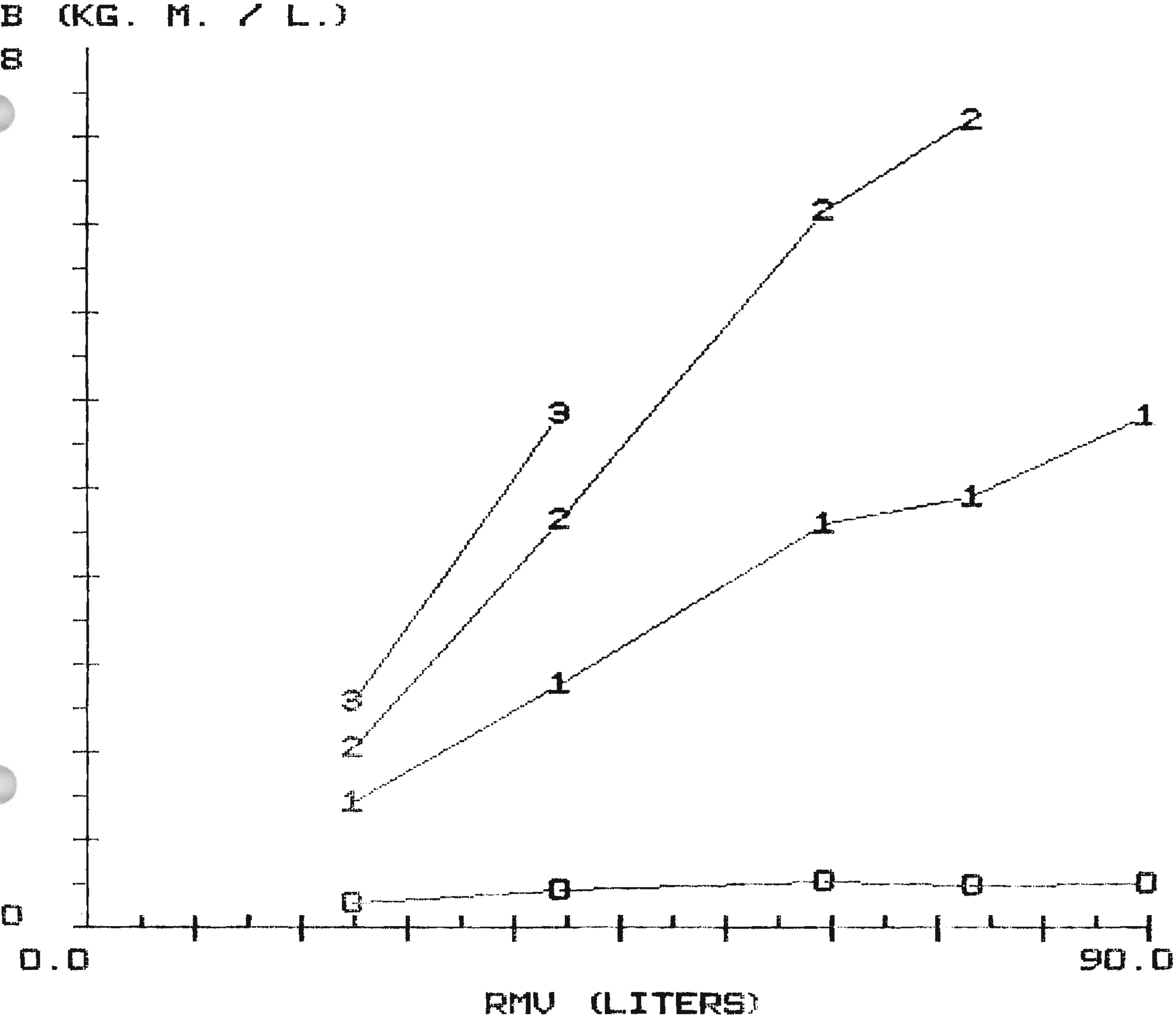


FIGURE 55:

0 = TESTS AT 0 FSW.
1 = TESTS AT 100 FSW.
2 = TESTS AT 200 FSW.
3 = TESTS AT 300 FSW.

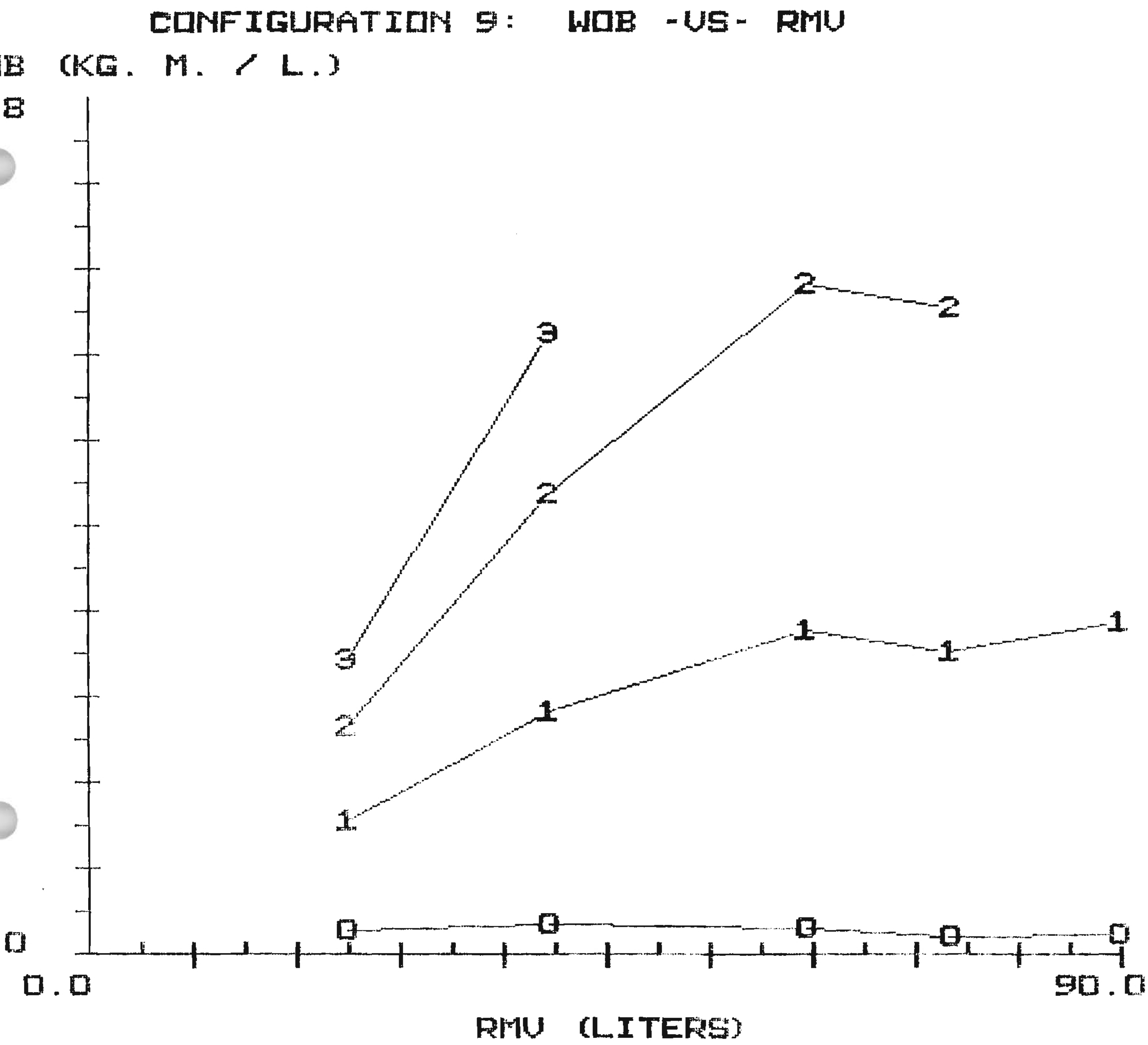


FIGURE 56:

0 = TESTS AT 0 FSW.
1 = TESTS AT 100 FSW.
2 = TESTS AT 200 FSW.
3 = TESTS AT 300 FSW.

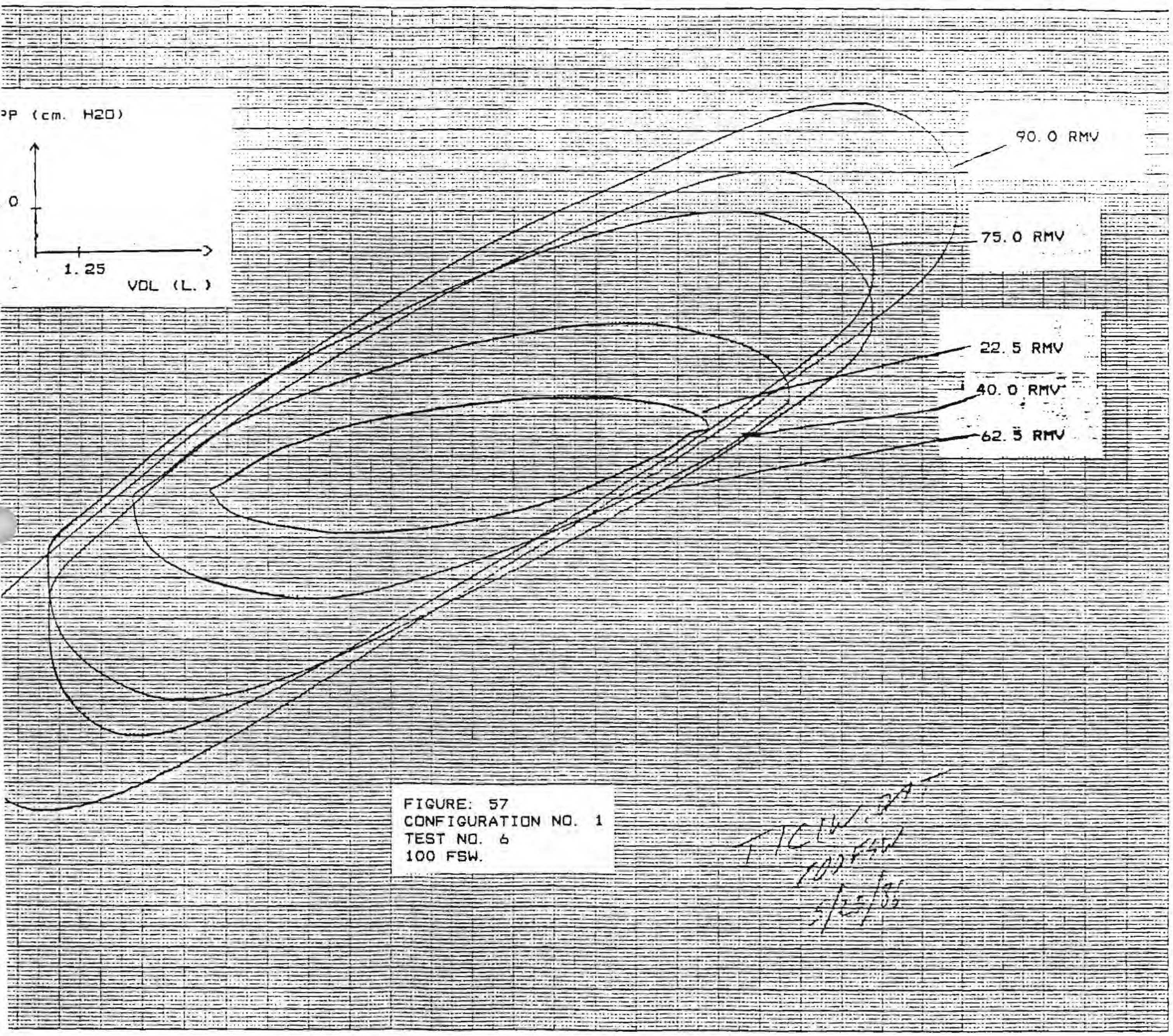


FIGURE: 57
CONFIGURATION NO. 1
TEST NO. 6
100 FSW.

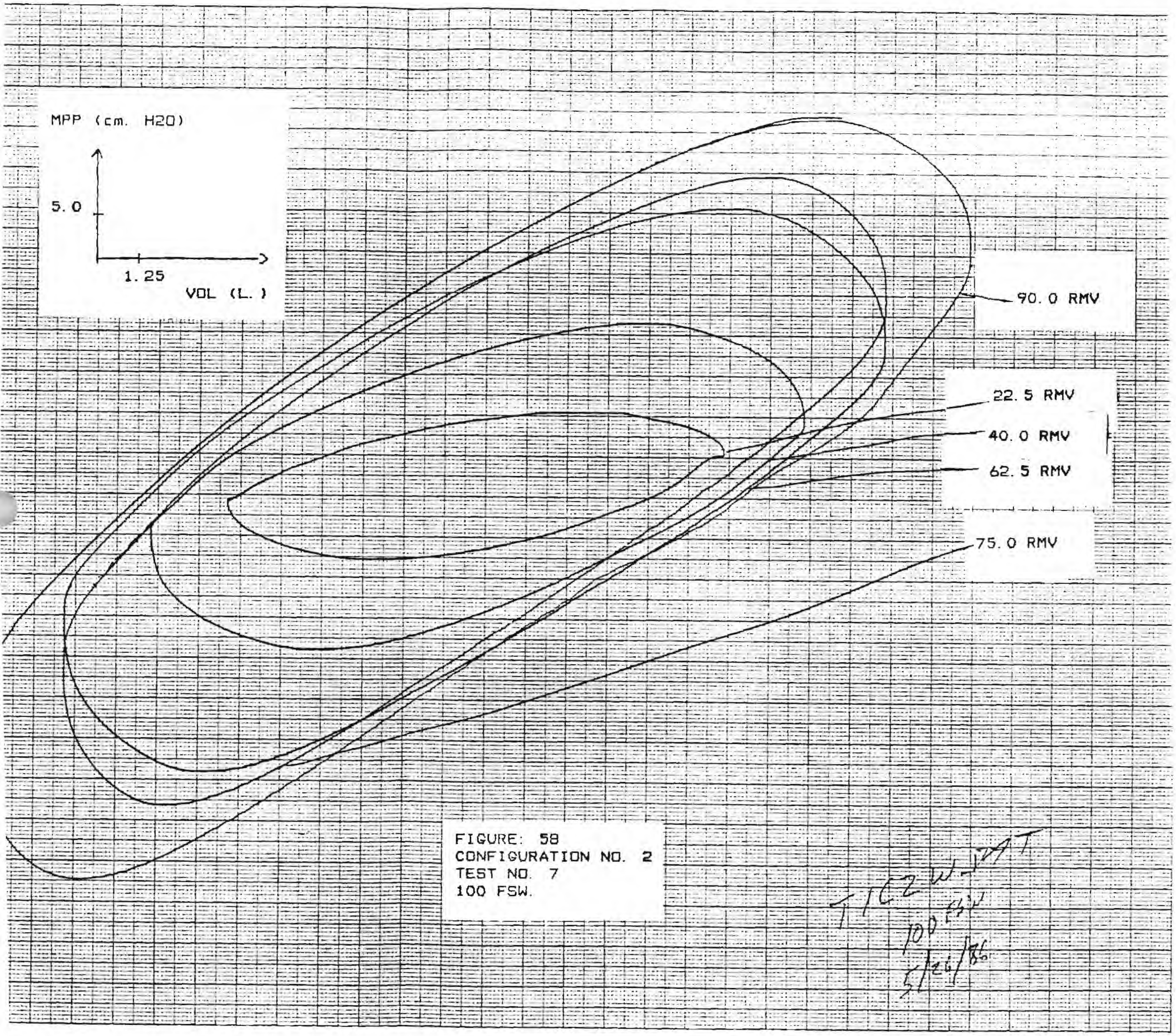


FIGURE: 58
CONFIGURATION NO. 2
TEST NO. 7
100 FSW.

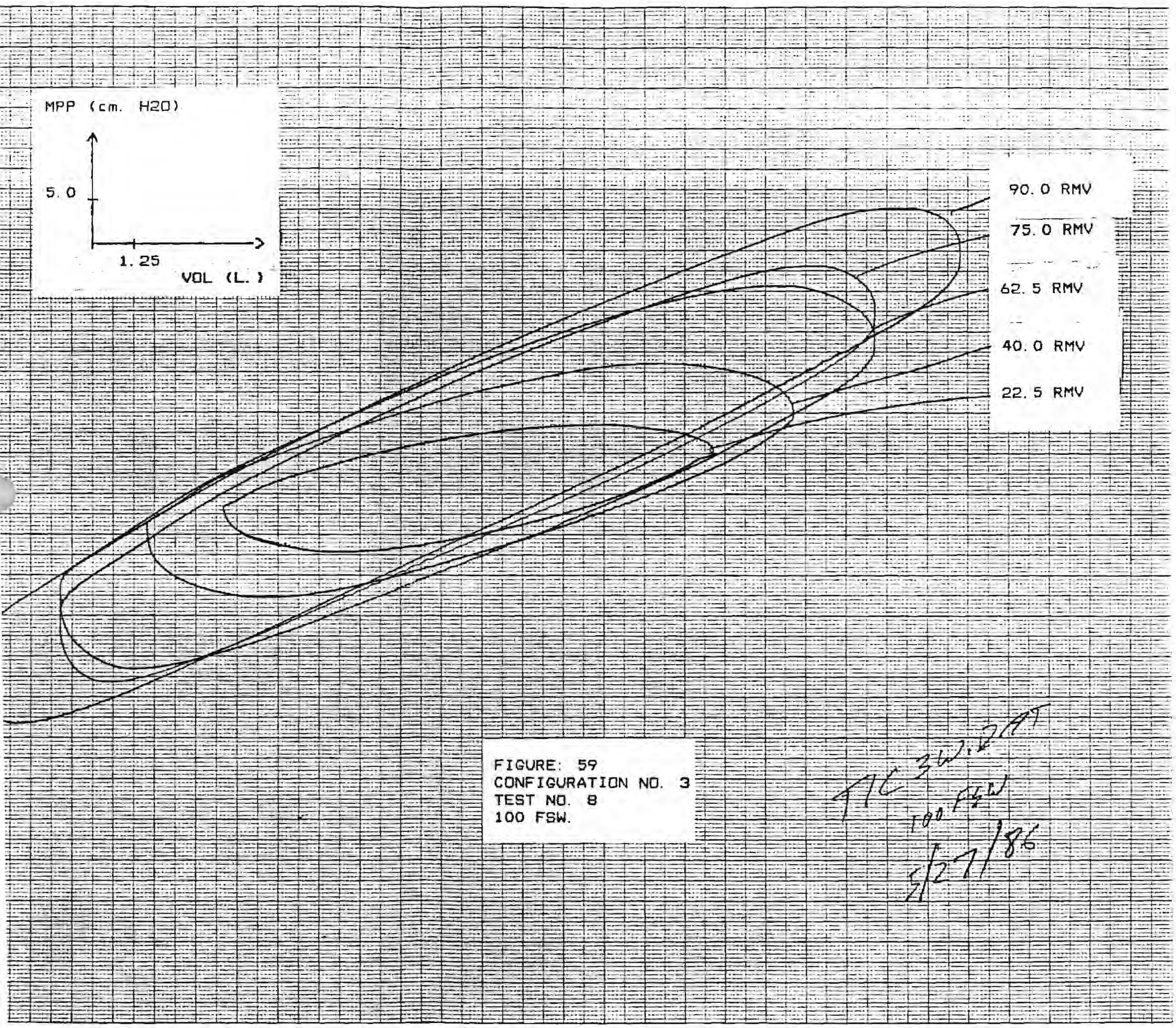


FIGURE: 59
CONFIGURATION NO. 3
TEST NO. 8
100 FSW.

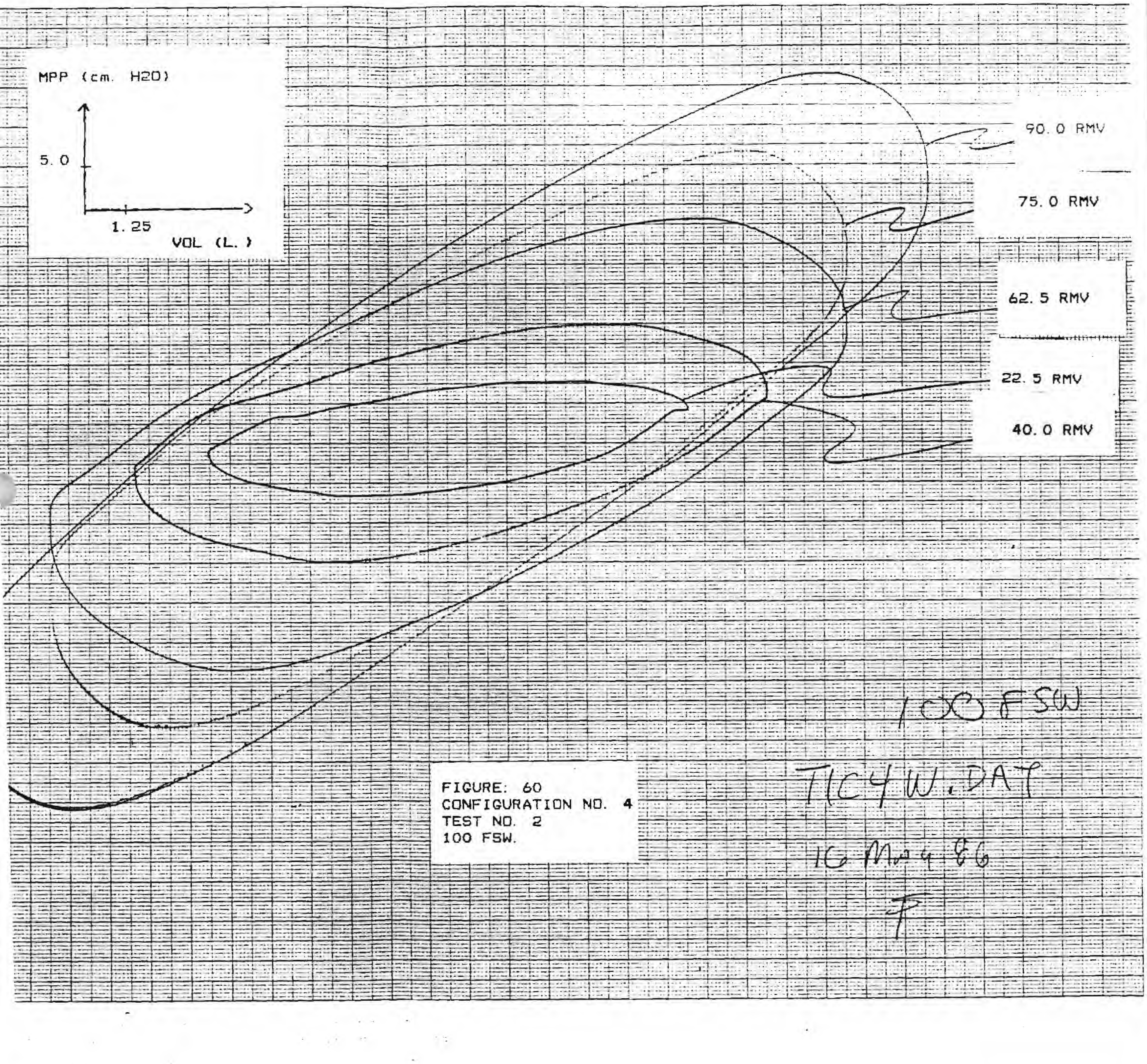


FIGURE: 60
CONFIGURATION NO. 4
TEST NO. 2
100 FSW.

Phase 1-B
Split Breathing Bag System
Breathing Resistance (Pc & Pm) and Work of Breathing (WB)
(TESTS WITHOUT LiOH IN CANISTER)

		Depth (fsw)											
		0			100			200			300		
Canister Config.	RMV (L)	Pc (cmH2O)	Pm (cmH2O)	WB km/l	Pc (cmH2O)	Pm (cmH2O)	WB km/l	Pc (cmH2O)	Pm (cmH2O)	WB km/l	Pc (cmH2O)	Pm (cmH2O)	WB km/l
(1)	22.5	-0.5	3.	0.01	0.4	15.	0.09	-0.1	19.	0.12	0.3	30.	0.20
.75 L/D	40.0	0.5	4.	0.01	0.1	24.	0.12	1.1	38.	0.20	0.9	57.	0.36
Radial	62.5	1.4	5.	0.01	-0.3	29.	0.08	2.0	58.	0.23	0.5	84.	0.35
200 ci	75.0	1.8	5.	0.01	-2.4	33.	0.06	-2.4	68.	0.18	-1.6	100.	0.27
	90.0	-1.7	6.	0.01	-1.5	44.	0.07	3.5	83.	0.18	4.3	123.	0.35
(2)	22.5	-0.9	7.	0.04	-0.4	15.	0.11	-0.2	20.	0.15	-0.2	26.	0.19
.25 L/D	40.0	-1.3	11.	0.06	0.3	30.	0.21	-0.4	41.	0.30	0.5	52.	0.39
Radial	62.5	2.1	18.	0.08	1.3	50.	0.35	1.1	77.	0.57	-0.5	95.	0.69
200 ci	75.0	-2.3	22.	0.09	2.8	68.	0.45	-0.7	104.	0.71	1.0	126.	0.92
to-out	90.0	2.5	24.	0.10	-2.0	82.	0.54	2.6	125.	0.88	XXXX	XXXX	XXXX
(3)	22.5	0.6	7.	0.03	0.2	15.	0.11	0.2	22.	0.16	-0.2	26.	0.19
.25 L/D	40.0	1.4	11.	0.04	0.6	29.	0.20	0.5	43.	0.31	0.4	54.	0.39
Axial	62.5	-1.4	14.	0.05	0.9	50.	0.33	0.8	79.	0.49	-0.4	103.	0.71
200 ci	75.0	1.5	16.	0.05	-0.9	63.	0.39	-0.8	105.	0.69	1.1	127.	0.90
	90.0	1.8	19.	0.07	-1.1	81.	0.48	-0.8	125.	0.83	XXXX	XXXX	XXXX
(4)	22.5												
Gortex	40.0												
Radial	62.5												
In-to-	75.0												
Out	90.0												
(5)	22.5	-0.7	6.	0.03	-0.4	14.	0.12	0.1	21.	0.16	-0.2	25.	0.18
.25 L/D	40.0	-1.1	10.	0.05	-0.7	26.	0.19	-0.2	41.	0.30	-0.4	52.	0.38
Radial	62.5	-1.4	14.	0.07	1.0	50.	0.35	-0.7	72.	0.51	0.6	96.	0.69
200 ci	75.0	1.1	17.	0.08	-0.7	64.	0.43	0.8	101.	0.69	0.5	124.	0.91
t-to-in	90.0	-1.7	20.	0.09	1.5	81.	0.53	1.4	121.	0.86	XXXX	XXXX	XXXX

ments: (1) Pc = Canister pressure drop
(2) Pm = Mouthpiece pressure drop
(3) XXXX = Data was not recorded due to the high pressures generated at these depths and RMV's.
(4) Configuration 4 was not tested without LiOH.

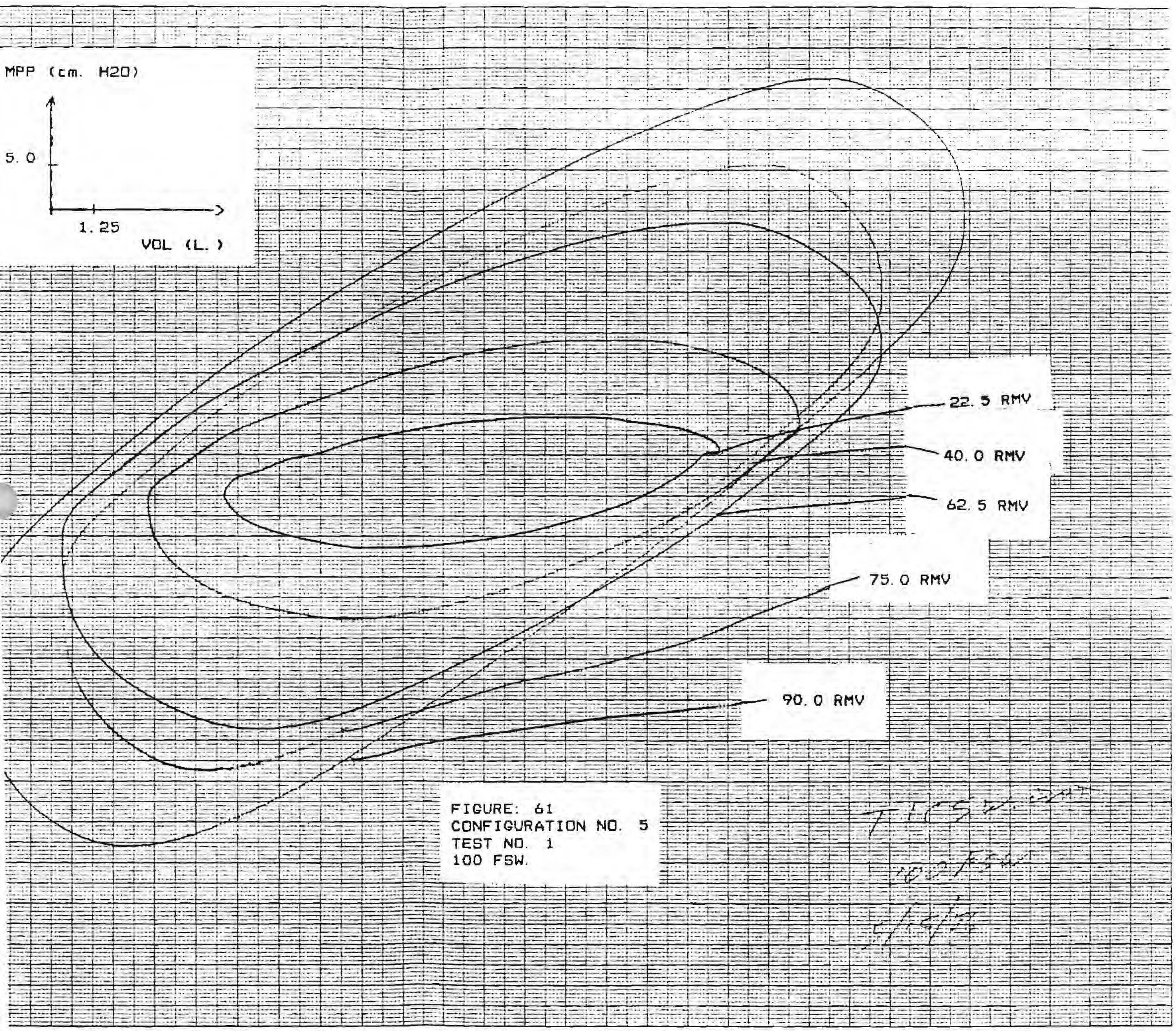


FIGURE: 61
CONFIGURATION NO. 5
TEST NO. 1
100 FSW.

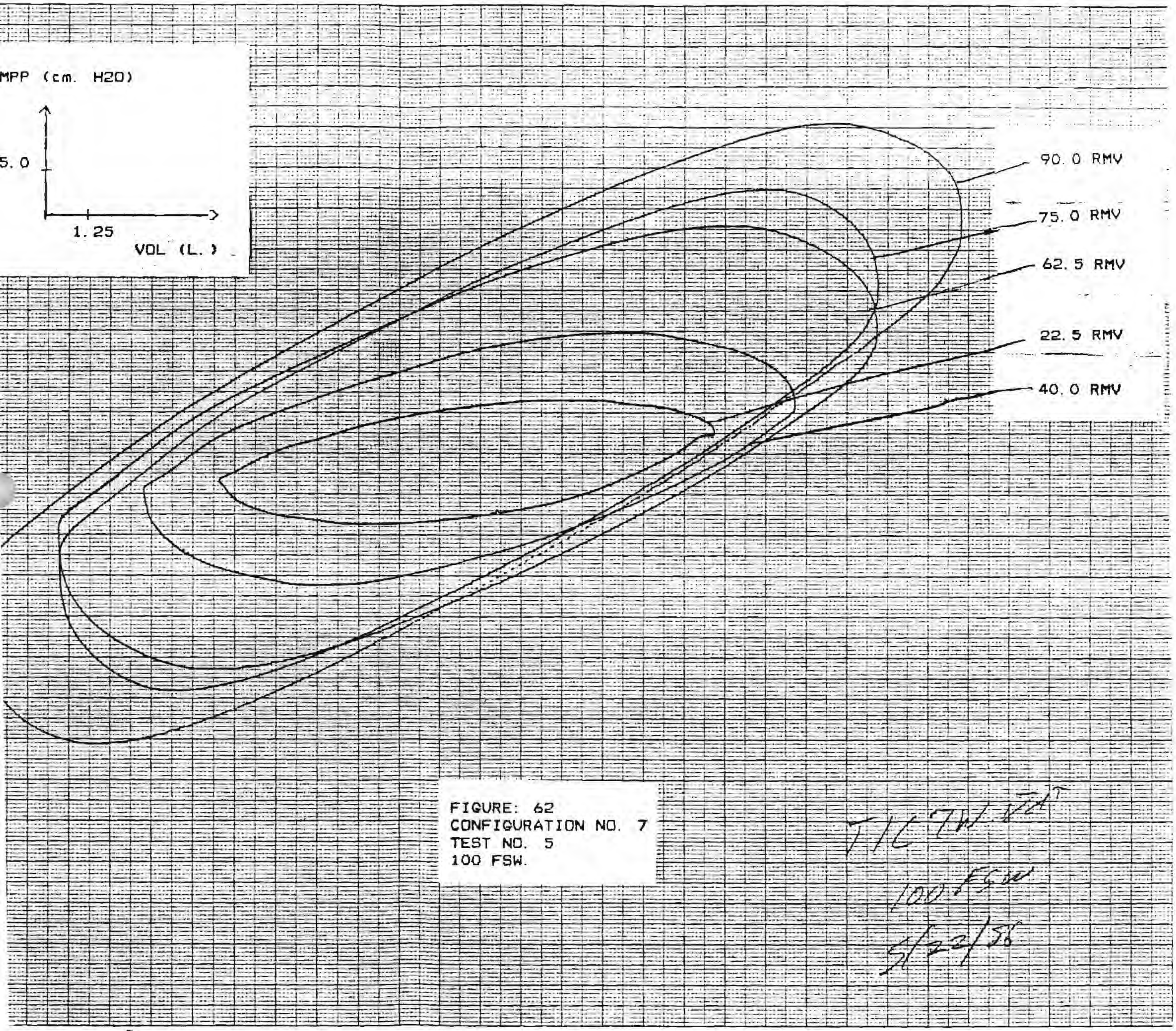


FIGURE: 62
CONFIGURATION NO. 7
TEST NO. 5
100 FSW.

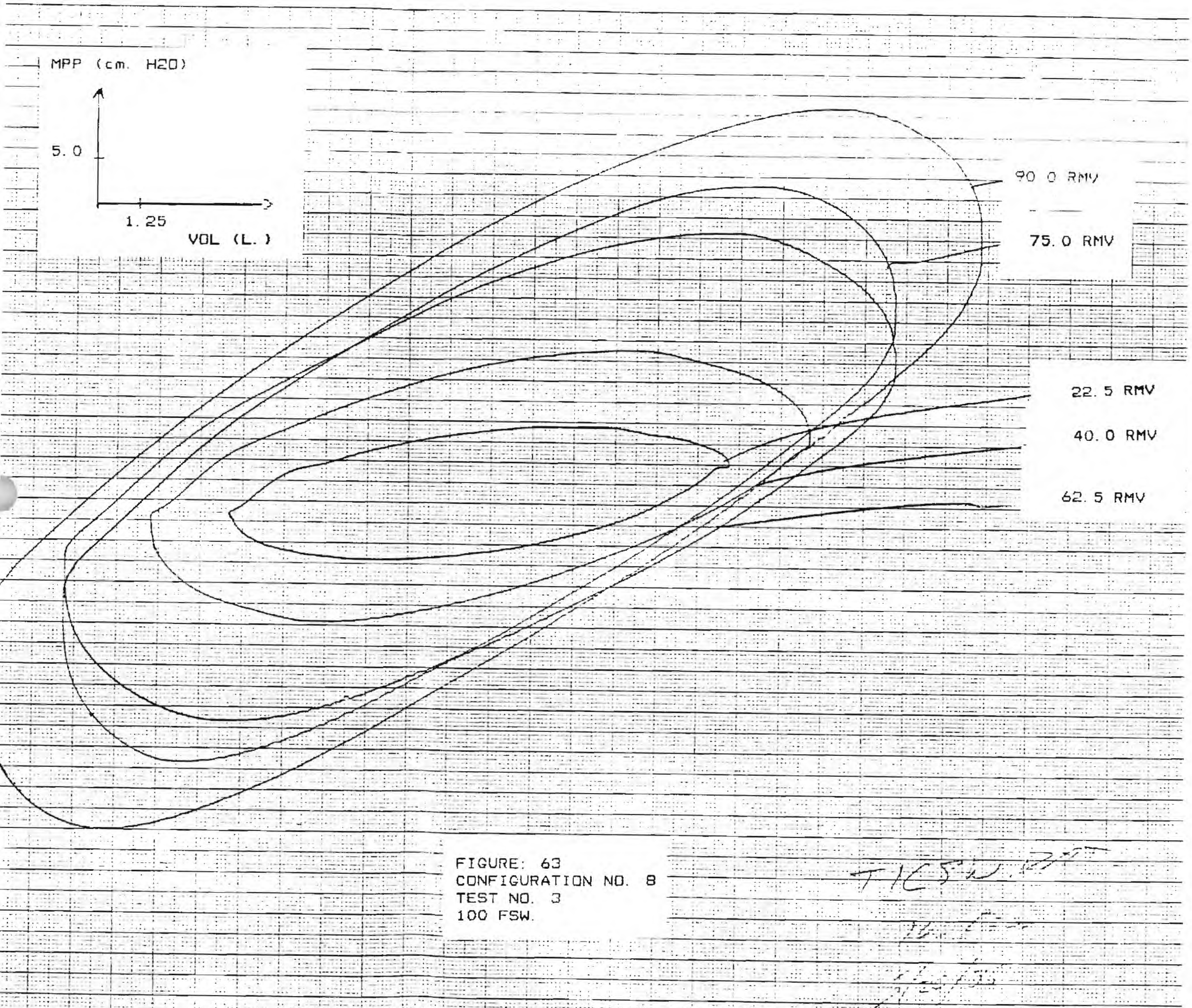
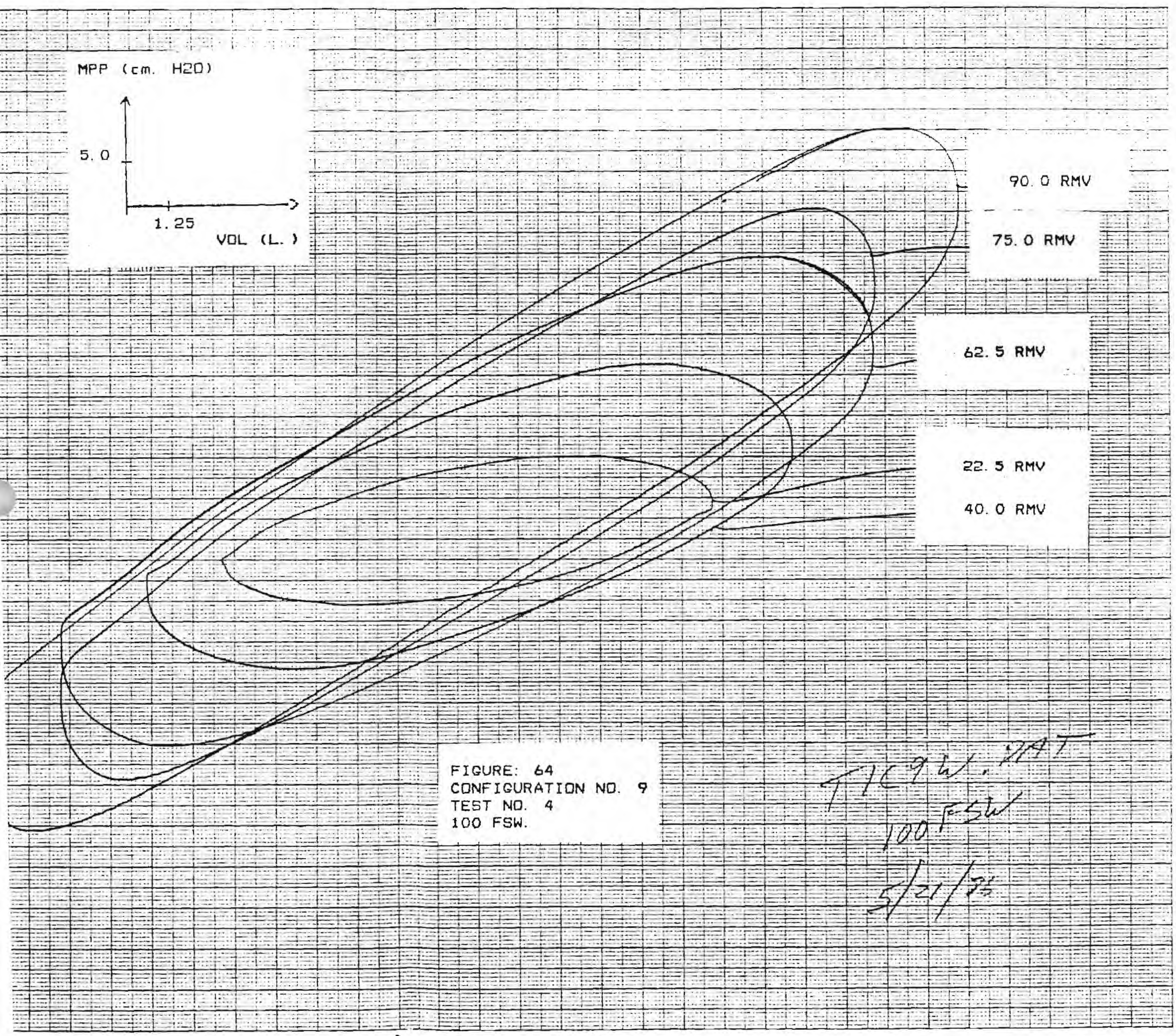


FIGURE: 63
CONFIGURATION NO. 8
TEST NO. 3
100 FSW.


MPP (cm. H2O)
5.0
1.25
VOL (L.)
90.0 RMV
75.0 RMV
62.5 RMV
22.5 RMV
40.0 RMV
FIGURE: 64
CONFIGURATION NO. 9
TEST NO. 4
100 FSW.
100 FSW
5/21/75

Unmanned Breathing Apparatus Test System

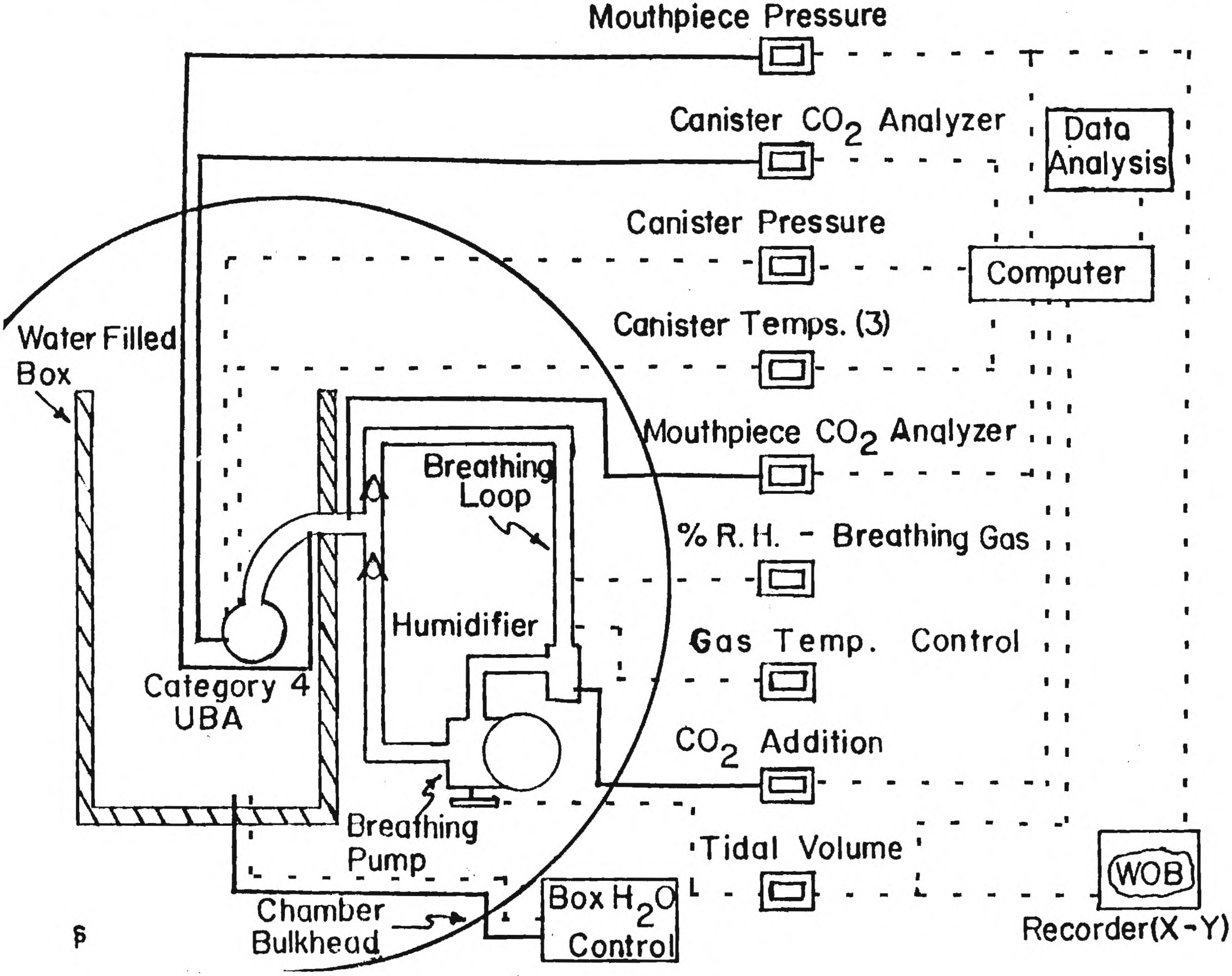


Figure 65:

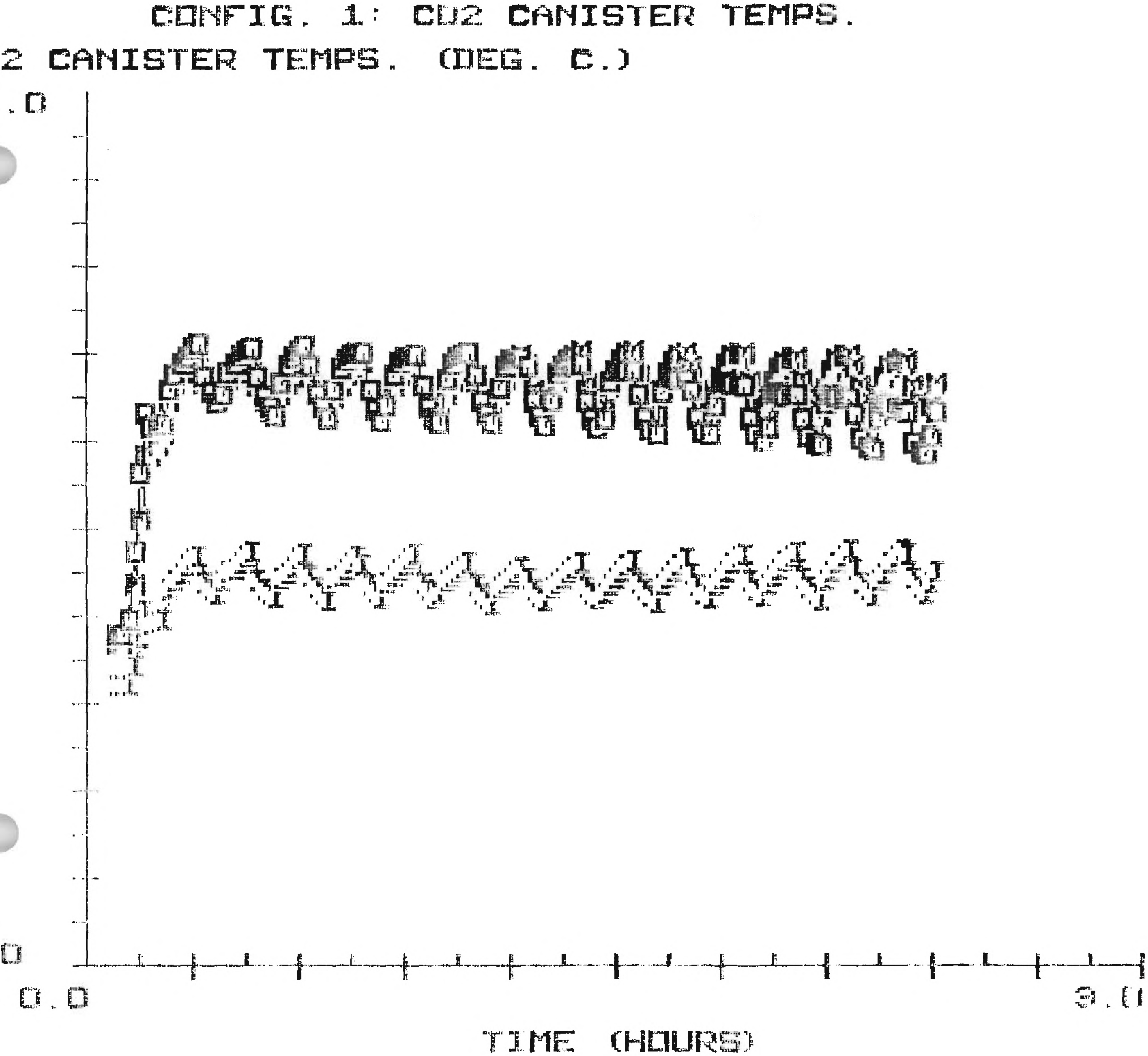


FIGURE 66:

I = CANISTER INLET TEMPS.
M = CANISTER MIDDLE TEMPS.
O = CANISTER OUTLET TEMPS.

CONFIG. 2: CO2 CANISTER TEMPS.

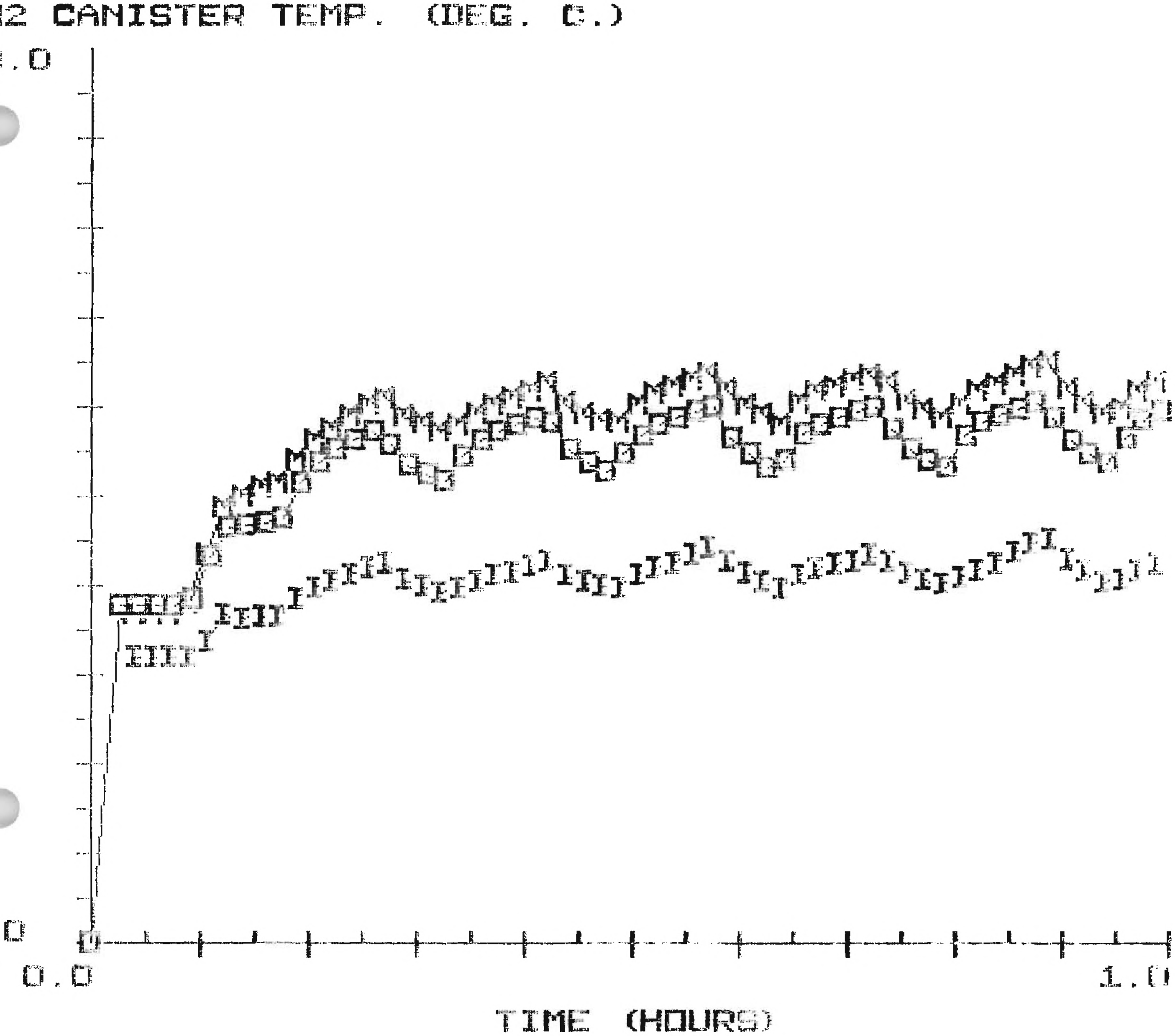


FIGURE 67:

I = CANISTER INLET TEMP. PROBE.
M = CANISTER MIDDLE TEMP PROBE.
O = CANISTER OUTLET TEMP PROBE.

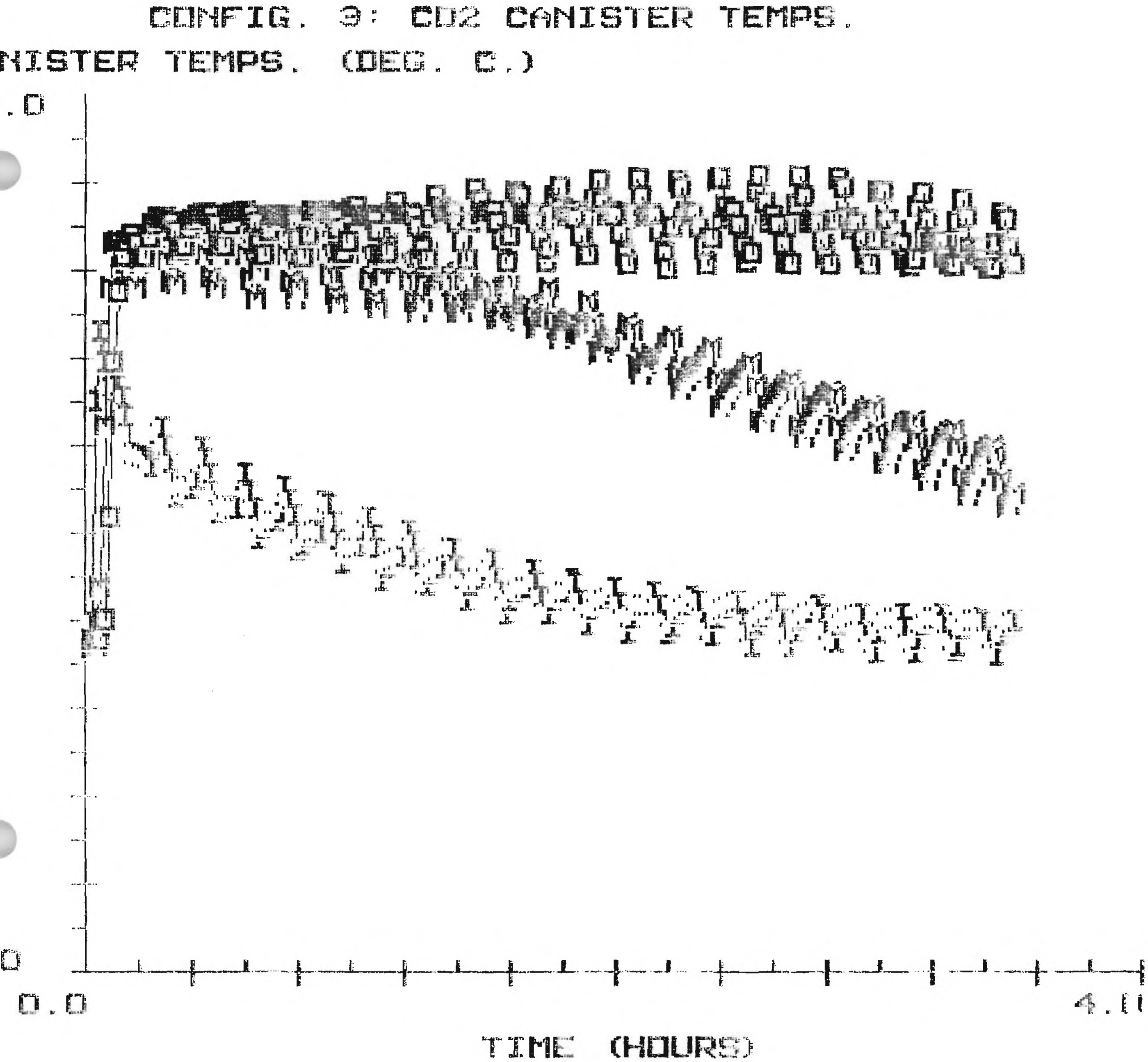


FIGURE 63:

I = CANISTER INLET TEMPS.
M = CANISTER MIDDLE TEMPS.
O = CANISTER OUTLET TEMPS.

REFERENCES:

1. NEDU Report No. 3-81 "Standardized NEDU Unmanned UBA Test Procedures and Performance Goal", J. R. Middleton and E. D. Thalmann, July 1981.

OTHER REFERENCES USED INDIRECTLY IN THIS INVESTIGATION:

NEDU Report No. 3-82 "Unmanned Evaluation of Six Closed Circuit Oxygen Rebreathers", J. R. Middleton, July 1982.

NEDU Report No. 5-79 "Evaluation of Modified Draegar Lar V Closed Circuit Oxygen Rebreather", J. R. Middleton and C. A. Piantadosi, August 1979.

Appendix A: GLOSSARY

ata.	Atmospheres absolute.
BPM	Breaths per minute.
B.T.	Canister Break Through: The point at which CO2 concentration in the inhaled breathing gas reaches 0.5 surface equivalent (SEV) unless specifically defined at a different percentage.
Can. Press.	Differential pressure across the back pack.
Can. Delta P.	Differential pressure across the back pack.
C/C	Closed circuit UBA.
CDS	(USN) Conventional Diving System
Cm. H20 or Cm. of H20	Centimeters of water pressure (differential).
CO2	Carbon dioxide.
deg. C.	Degrees Celcius.
deg. F.	Degrees Farenheit.
Delta P.	Differential pressure across a component.
FGHL	F.G. Hall Hyperbaric / Hypobaric Environmental Laboratory at Duke Univ. Medical Center.
fsw	Feet Sea Water.
FPM	Feet per Minute.
HP	High Pressure.
Kg. M. / L.	Breathing work in kilograms - meters per liter.
L.	Liters.
LPM	Liters per Minute.
MPP	Same as Peak MPP.
NCSC	Naval Coastal Systems Center

NEDU	(U.S.) Navy Experimental Diving Unit
P.	Pressure.
Peak MPP	Peak inhalation to peak exhalation differential pressure at the mouthpiece.
PPM	Parts per million.
psig	Pounds per square inch, gauge.
RH	Relative Humidity.
RMV	Respiratory Minute Volume (L.)
SEV	Surface Equivalent Volume.
tidal volume	Volume of air breathed in and out of the lungs during a normal respiration.
UBA	Underwater Breathing Apparatus.
UBATS	Unmanned Breathing Apparatus Test System.
USN	United States Navy

Appendix B: UBATS Description.

DUKE UNIVERSITY MEDICAL CENTER
F. G. HALL ENVIRONMENTAL RESEARCH LABORATORY
UNMANNED BREATHING APPARATUS TEST SYSTEM (UBATS): A SYSTEM TO TEST UNDERWATER BREATHING APPARATUS (UBA)

The F. G. Hall Environmental Research Laboratory at Duke University has been a leader in space and diving research for over two decades. In space, the Hall Lab has been involved in the development of life support equipment and procedures for the Mercury and Gemini programs and more recently in studies of decompression procedures for the Space Shuttle and Space Station. In diving, Hall Lab activities have included the development of decompression procedures for the Navy and commercial diving companies, the performance of welding and breathing apparatus tests, the coordination of the Diver's Alert Network (DAN), the conduct of deep Nitrox and Heliox dives including the world record Atlantis Dive Series, the investigation of diving accidents and fatalities, and the development of Underwater Breathing Apparatus (UBA). Studies of the design and optimization of carbon dioxide removal canisters are currently in progress.

In support of UBA development and testing, the Hall Lab has designed, fabricated, and assembled an Unmanned Breathing Apparatus Test System (UBATS) following U. S. Navy guidelines. The system can simulate human respiratory work ranging from rest to hard exertion under environmental conditions from extreme altitude to the depths of an oceanic continental slope. UBATS simulates operating conditions and measures performance parameters for all categories of UBA's in use today. The data obtained during UBA tests can be directly compared to existing performance specifications, can be used to identify UBA component deficiencies, and can be used to determine if an UBA is safe for manned testing.

The categories of UBA design, the parameters which UBATS controls, and the UBA parameters which UBATS measures are listed below (ref. NEDU Report No. 3-81).

UBATS CAN TEST THE FOLLOWING CATEGORIES OF UBA

CATEGORY 1. Open-circuit demand UBA (SCUBA).
CATEGORY 2. Open-circuit umbilical-supplied demand UBA (full-face masks or diving helmets in demand mode).
CATEGORY 3. Open-circuit umbilical supplied free-flow UBA (full-face masks or diving helmets in free-flow mode).
CATEGORY 4. Closed circuit and semi-closed circuit diver breath driven UBA (U. S. Navy's Mark 16 and Mark 11 UBA).
CATEGORY 5. Closed circuit and semi-closed circuit pump or

ejector driven UBA (push-pull diving systems).

CONTROLLED PARAMETERS

1. PRESSURE
   UBA can be tested at pressures ranging from one torr (space applications) to 3600 feet of seawater (over 1600 p.s.i.).
2. AMBIENT ENVIRONMENTAL CONDITIONS
   Tests can be conducted in a wet or dry environment at ambient temperatures from 30 to 100 degrees F.
3. EXHALED BREATHING GAS TEMPERATURE
   Simulated exhaled breathing gas temperature can be varied from 70 to 100 degrees F.
4. EXHALED BREATHING GAS HUMIDITY
   Simulated exhaled breathing gas humidity can be controlled (normally 90% RH).
5. BREATHING RATE AND VOLUME
   Respiratory rate can be set at between 10 and 30 breaths per minute. Respiratory volume (tidal volume) can be set at 1, 1.5, 2, 2.5, or 3 liters. Both parameters can be remotely changed at pressure to give Respiratory Minute Volumes (RMV - the volume of gas breathed in one minute) which simulate any work load from rest (15 liters per minute - lpm) to heavy work (90 lpm).
6. OXYGEN CONSUMPTION
   Oxygen consumptions from rest to heavy work can be simulated.
7. CARBON DIOXIDE (CO_2) PRODUCTION
   CO_2 production from 0 to 3 lpm can be simulated.
8. BREATHING GAS COMPOSITION AND PRESSURE
   Oxygen, Nitrox (Nitrogen/Oxygen), Heliox (Helium/Oxygen), Trimix (Helium/Oxygen/Nitrogen), or air can be supplied. Pressures to the first or second stage of a regulator, or any intermediate point in any UBA can be controlled from 0 to 3000 psig.
9. RESPIRATORY PATTERN
   A sinusoidal respiratory pattern is used.
10. PARAMETER CONTROL AND MEASUREMENT
    UBA test parameters and UBATS control parameters are sampled, stored, and analyzed by digital computer.

MEASURED PARAMETERS

1. MOUTHPIECE PRESSURE
   Changes in mouthpiece pressure are an indication of respiratory resistance within an UBA. Mouthpiece pressure is measured relative to ambient pressure during both inspiration and expiration. Maximum inspiratory and maximum expiratory pressures are also recorded.
2. TIDAL VOLUME
   The tidal volume (amount of gas inspired or expired in one breath) is measured.
3. WORK OF BREATHING
   Work of Breathing (WOB) is a measure of the amount of respiratory work needed to "drive" an UBA. It is a function of the tidal volume and mouthpiece pressure. Simulated lung volume and mouthpiece pressure are plotted on an X-Y recorder. The area of the generated loop is the WOB. The WOB is also determined by a digital computer.
4. CARBON DIOXIDE PERCENTAGE
   CO2 percentages can be measured at any point in the UBA. This might be useful for breath-by-breath CO2 analysis at UBA mouthpiece, at the inspiratory side of a closed-circuit UBA CO2 absorbent canister, or in the return line of a push-pull system.
5. UBA TEMPERATURES
   UBA temperatures can be measured at the mouthpiece, at gas heater hot water inlets, in CO2 absorbent beds, and at other sites.
6. PRESSURE DROP ACROSS UBA COMPONENTS
   Pressure drops across UBA components, such as in-line filters or CO2 absorbent beds, can be measured.
7. INTERMEDIATE UBA GAS PRESSURES
   Gas pressures at any point in the UBA can be measured and recorded. For example, supply pressures to the first and second stages of a demand regulator can be measured independently.

Appendix C: UBATS Test Procedure.

I. PRETEST PROCEDURE

A. START UP PROCEDURE

1. Air on? (outside bank,pilot air,inside bank)
2. Nitrogen on? (put up Golf green line)
3. Set chiller temp.
4. Set valves in water system for recirculation through the holding tank (Tank Fill open, Tank Drain open, Pump Supply open, Bypass open, Arc Fill closed, Arc Recirc. closed, and Arc Drain closed.
5. Turn on water system pump. Check for circulation.
6. Obtain desired water temp.
7. Power up instrumentation. (Turn on outlet strip)
8. Turn computer on.

```
     -screen will show
                                  Start?
     -type:
                                  DY0(return)
     -screen:
                                  RT-11SJ V04.00A
                                  Enter today's date:
     -type:
                                  (day-month-year)(return)
     -screen:
                                  Enter current time:
     -type:
                                  (military time)(return)
     -screen:
                                  .
     -Put data disc in right drive (DY1)
     -type:
                                  DIR
     -screen:
                                  Files stored on disc,
                                  number of free blocks.
                                  (Make sure there is enough
                                  storage space on the disc,
                                  450 free blocks.
                                  If not, delete oldest
                                  file)
     -type:                       del filename.dat
     -screen:                     are you sure?
     -type: (y or n)
     -type:                        R NCSC1(return)
```

9. Turn on temperature indicators. Check red line.
10. Turn on blowers.
11. Set chamber temperature controller on cool.
12. Open excursion line to chamber and check regulator inside for 60 psi setting.
13. Set N2 at 200 psi on the Golf orange bib line.
14. Set all timers to 00000.
15. Close mouthpiece drain, bubbler drain, mixing box drain, and fill the manometer with water.

16. Calibrate LVDT (see LVDT calibration procedure)
17. Turn on ventilator (3.0 l. at 15 BPM).
18. Go through one cycle of tidal volume changes -lubricate if necessary.
19. Set tidal volume on 1.5 liters
    Set breathing frequency at 15 BPM.
20. Turn on mouthpiece temperature controller only. Make sure the correct temperature is set according to the following table:

Arc Temp	-2C/29F	4.5C/40F	21C/70F
Breathing Loop Temp	23C/80.0F	28.6C/83.5F	30.4C/97.5F

21. Calibrate canister delta-p (see Canister Pressure Transducer Calibration Procedure)
22. Calibrate mouthpiece pressure (see MP Pressure Transducer Calibration Procedure).
23. Calibrate CO2 analyzer (0.0 - 4800.0).
24. Calibrate mass flow (see Mass Flow Meter Calibration Procedure). 00.4-23.5 ext of Validyne = 0.00-2.00 on amplifiers.
26. Fill bubbler with warm water.
27. Make sure that the CO2 flow is to the bubbler.
28. Pressure test rig to 20 cm H2O. Leak rate must be below 5 cm H2O per minute.
29. Run a test file (xxx.dat) on the computer and check calibration values and test values.
30. Secure the inside hatch, medical lock, check the chamber, and secure the chamber door.

I. PRETEST PROCEDURE (cont.)

B. UBA PREPARATION:

1. Weigh UBA w/o absorbent (empty weight).
2. Charge UBA w/ absorbant. Tamp down the absorbent after each temperature probe is put in place.
3. Weigh UBA (Must be within 50g of CAN charge normal weight).
4. Record charged weight and absorbant weight and convert to units of lbs. Use 2.20462 lbs/kg to convert
5. Secure all fasteners tightly and grease O-rings if needed.
6. Dip test.
7. Make sure breathing bag(s) are free to inflate.
8. Check all mouthpiece valves.
9. Check for damage in sample, pressure, and air add lines.
10. Blow out sample lines.
11. Secure rig on the pulley above the arc.
12. Hook up pressure and sample lines:
    - CO2 sample on inhalation side
    - air add on exhalation side
    - line from canister transducer to inhalation side
    - line from canister solenoid to exhalation side.
13. Put weights on the rig, if required.

II. TEST PROCEDURE

A. WORK OF BREATHING (WOB) TESTING

1. When holding tank water is at set temperature, fill the arc.(put fill hose in bucket, open ARC FILL, close BYPASS, fill bucket, put hose in arc.)
2. When arc is full, open ARC RECIRC and close PUMP SUPPLY.
3. Check water temperature. (should be +/- 2C of the set temp of 4C for WOB tests)
4. Start computer acquisition:
   screen: Recalibrate any instrument (y or n).
   type: n (return)
   screen: Filename?
   type: Filename.dat (return)(filename = 6 letters max)
   screen: Test number?(integer)
   type: Eg. 1 (return)
   screen: UBA configuration number(integer)
   type: Eg. 1 (return)
   screen: sample rate?(integer)
   type: Eg. 10 *when a (return) is hit data acquisition starts.
5. Put chart paper on X-Y plotter
   -mark depth, filename, and date at top of paper.
   -fill out UBADAT sheet.
6. Start X-Y plotter
   (line=ON, chart=HOLD, servo=ON, pen=LIFT)
7. Set tidal volume and frequency (see the table in step 14).
8. Look for at least three stable WOB values(+/-.01).
9. Get a loop by shifting pen to RECORD for one cycle
10. Shift back to LIFT.
11. Stop X-Y plotter by shifting servo to STANDBY.
12. Mark loop as to number (test number,loop number) and computer time.
13. Start X-Y plotter.
14. Repeat steps 5-13 except change step 7 for these RMV's:
    1. 22.5 = 15 BPM at 1.5 LPM.
    2. 40.0 = 20 " at 2.0 " .
    3. 62.5 = 25 " at 2.5 " .
    4. 75.0 = 30 " at 2.5 " .
    5. 90.0 = 30 BPM at 3.0 LPM.
15. Turn on N2 (flowmeters should be set at 5.0 l).

II. TEST PROCEDURE (cont.)

16. Compress to first test depth.
17. To compress:
    a. Breathing frequency should be on lowest speed.
    b. Open breathing loop solenoid.
    c. Open calibration solenoid V8.
    d. MP calibration switch to V5, CAN cal. switch to V7.
    e. Close calibration system supply (ball valve).
    f. Make sure chamber temperature controller is on cool - both blowers on.
    g. Slowly turn in compression rate control to about 15 psi (at the surface turn in fast to get a seal then back off to 10 psi.)
    h. Watch depth, press transducers, inside chamber.
    i. When depth is achieved, back off compression rate controller. Wait 2 min. Makeup depth if necessary.
    j. Open air add solenoid, if required.
    k. Open calibration supply valve (ball valve)
    l. Close breathing loop solenoid.
    m. Close calibration solenoid.
    n. Close air add soleniod when breathing bags are sufficiently full.
18. Repeat steps 5-14.
19. Compress to next test depth following compression procedure.
20. Repeat steps 5-14.
21. Continue at all test depths.
22. Repeat steps 5-14.
23. Do CO2 test at appropriate depth.
24. Stop Data Acquisition by hitting (ctrl)(c) <u>once</u>.

B. CO2 TESTING

1. Achieve test depth and allow at least 30 min in water.
2. Check arc water temp should be +/-2C of set temp.
3. Check humidity (check MP and CAN temperatures).
4. Set tidal volume on 2.0 liters.
5. Set breathing frequency at 25 BPM.
6. Turn on CO2 bottle.
7. Start data aquisition if not already running.
8. To start test:
   Put work/rest controller to auto and turn work/rest controller on and hit reset. Start timer. Record start in computer time.
9. Make sure breathing bags fill sufficiently.
   If not, add air through air add solenoid, if appropriate.
10. Do a set of WOB loops at the beginning of each CO2 test.
11. Open CO2 sample line to CO2 analyzer. Set flow to 1.0 liters/min.
12. Record when analyzer reads .5%SEV and .88%SEV.
13. Do a set of WOB loops at the end of each CO2 test.

III. POST TEST PROCEDURE

1. To Decompress:
   a. Set breathing frequency to lowest speed.
   b. Open breathing loop solenoid and cal solenoid.
   c. Set MP cal switch to V5 and can cal switch to V7.
   d. Close cal system supply (ball valve)
   e. Change chamber temp control to heat and turn on both hot water valves.
   f. Open bottom chamber exhaust valve.
   g. Slowly turn in decompression rate controller.
   h. Open manual chamber exhaust valves slowly.
2. Turn off heat tapes.
3. Close all valves when chamber hits surface.
4. Back off decompression rate control.
5. Turn off hot water valves.
6. Turn chamber temp control to cool.
7. Turn off N2. CAUTION !! Do not enter the chamber until chamber air has been circulated for 10 min. with a fan.
8. Turn off ventilator pump.
9. Drain arc and set up for next test.
   SAME DAY
   - Open Bypass and close Arc Fill until the water level is below the mouthpiece connection
   - Open Arc Fill and close Bypass.

   NEXT DAY
   -Turn off water pump.
   -Open Arc Drain.
   -Open Pump Supply.
   -Open Bypass.
   -Close Arc Fill.
   -Close Arc Recirc.
10. Disconnect mouthpiece connection.
11. Raise test stand.
12. Drain bubbler, mixing box, mouthpiece.
13. Disconnect pressure and sample lines.
14. Remove canister from test stand and weigh.
15. Dispose of absorbent using a plastic bag outdoors.
16. Clean and dry all parts.
17. Record data in footnotes by answering terminal screen: enter footer data? (y/n)
    type: y (return)
18. Copy data onto hard disc.
19. Get a printout of data and put in notebook.

Appendix D:

A Brief History of the Aquisition and Use of Lithium Hydroxide (LiOH) for the NCSC Canister Development Project

INTRODUCTION

The F. G. Hall Laboratory Engineering Group has a contract with the Naval Coastal Systems Center (NCSC) to test and evaluate canisters. The canisters are components of a closed-circuit breathing apparatus which is now under development. The canister is to contain the CO2 absorbant LiOH. The evaluation will be based primarily on the canister's efficiency, the amount of CO2 it absorbs for a given amount of LiOH before allowing a set amount of CO2 to pass through. The variable parameters were depth (100 and 300 fsw), water temperature (29, 40, and 70 degrees F.), and configuration (three different size canisters were combined with two canister inserts to form five configurations). Configurations 2 and 5 used the same insert so there four different packing weights for the five configurations.

The following report relates our experiences with LiOH and its manufacturer, Poly Research Corp. The recorded data show that differences in the LiOH which we received produced erroneous results causing extra testing to be done. This additional testing, which was very time consuming, was necessary 1) to find the reason for the data's nonreproducibility and 2) to properly evaluate the canisters' performances.

September 1985:

Contacted Foote Mineral Company, Exton, Pa. (215) - 365 - 6750

Inquired about CO2 absorption grade LiOH.

Contacted Lithium Corp. of America

Inquired about CO2 absorption grade LiOH

Lithium Corp. of America does not manufacture CO2 grade LiOH.
Suggested Poly Research Corp. as a probable source.

1 August, 1986
NCSC Phase I CDS Development Project

Contacted Poly Research Corp., Deer Park, NY (516) - 242 - 1020

nquired about CO2 absorption grade LiOH

Spoke with Mr. Bob Wohl.
Suggested use of 6 x 14 mesh anhydrous LiOH which used by the U.S. Navy
Mil. Spec. with an absorption capacity of 0.7 g. CO2 / g. absorbant

October 2, 1985

Contacted Mr. Bob Wohl of Poly Research Corp.

Ordered 700 lbs. anhydrous LiOH, 6 x 14 mesh, 0.7 g. CO2 / g. absorbant
(Mil. Spec.)
Unit price = $16.00/lb.
Total price = $11,200.00
Delivery = 8 weeks
To be shipped in 25 lbs. drums.
Purchase Requisition sent to Sponsored Programs, Duke University
Duke Purchase Order Number = HX539583-J
Poly Research Order Number A-9970

October 24, 1985

Contacted Poly Research Corp. to change the order.
Spoke with Rob Finesmith.
Verbally ordered 200 lbs. of anhydrous LiOH (Mil. Spec.).
Unit price remained the same.
Total price = $3,200.00

December 20, 1985

Did not receive the LiOH from NCSC, as previously agreed.
Contacted Poly Research Corp.
Delivery delayed due to transportation problems.
Poly Research promised delivery by January 9, 1986.

January 9, 1986

Meeting with Jim Middleton, Project Manager.
He brought 25 lbs. anhydrous LiOH, 0.8 g. CO2 / g. LiOH from NCSC.
The LiOH was 4 x 14 mesh, from Lot No. 110HC, Foote Mineral Corp.
Used approx. 8 lbs. in a canister test to check the test system.

January 21, 1986

Received 200 lbs. LiOH, Lot Number 186LH, in a cardboard barrel. The LiOH was double wrapped in plastic. Barrel 1 was shipped by Direct Shippers, West New York, NJ, (201)-332-3906
Began testing with LiOH from Barrel 1.

January 28, 1986

Contacted Poly Research Corp.
Ordered 300 lbs. anhydrous LiOH (Mil. Spec.).
Unit price remained the same.
Total price = $4,800.00
Delivery = 10 days.
Duke Purchase Order Number HX 518438-A
Poly Research Order Number A-9970

February 11, 1986

Received 300 lbs. anhydrous LiOH, Lot Number 186LH, shipped in two containers:

(1) 200 lbs. barrel, to be referred to as Barrel 2.
(1) 100 lbs. barrel, to be referred to as Barrel 3.

Shipped by Direct Shippers, West New York, NJ.

March 6, 1986

Began testing with Barrel 2. Noted heavier packing weights, shorter durations, and decreased efficiency causing large variations in data. This is shown in Table D1.

March 19, 1986

Placed desiccant (silica gel wrapped in a towel) in Barrels 2 and 3.
Barrel 2 containing desiccant will be referred to as Barrel D2.
Barrel 3 containing desiccant will be referred to as Barrel D3.

April 15, 1986

Compared LiOH weights from Barrels D2 and D3 with the average weights from Barrels 1 and 2 for the same containers. See Tables D2, D3, and D4.

Table D1

Canister Efficiencies for Repeated Tests

This table shows the effect that the LiOH from Barrel 2 had on the reproducibility of test results. Tests that were repeated using LiOH from the same barrel showed good reproducibility. Tests using LiOH from Barrel 2 had substantially lower efficiencies than tests using LiOH from Barrel 1.

Config. No.	Depth/Temp (fsw/deg.F.)	Barrel No.	Efficiency (lb.CO2/lB.LiOH)
1	100/29	1	0.24
	100/29	2	0.16
	100/40	1	0.34
	100/40	1	0.37
	300/29	1	0.21
	300/29	2	0.11
	300/40	1	0.22
	300/40	1	0.22
3	300/70	1	0.45
	300/70	2	0.20
	300/40	1	0.42
	300/40	1	0.37
4	100/29	1	0.48
	100/29	2	0.20
	100/29	2	0.25
	100/40	1	0.45
	100/40	1	0.36
	300/29	1	0.47
	300/29	2	0.21
	300/70	1	0.34
	300/70	1	0.36

Table D2
LiOH Weight Comparison for Barrels 1 and 2

The weights recorded are averages of canister fills in completed tests. The actual weights for each test are listed in Tables D5 through D8. The weights used to compute the average weights for fills from Barrel 2 are from tests prior to 3/19/86, the date that desiccant was introduced into Barrels 2 and 3. No tests were done using LiOH from Barrel 2 for configurations 2 and 5 prior to 3/19/86.

Configuration No.	Barrel 1 (Avg. kg.)	Barrel 2 (Avg. kg.)	Wt. Change (%)
1	1.461	1.824	+25%
3	1.575	1.923	+22%
4	3.619	4.345	+20%

Table D3
LiOH Weight comparison for Barrels 2 and 3

The weights recorded below are from three fills of the insert for canister configuration number 1 using LiOH from Barrels 2D and 3D. At the time of these trial weighings, the desiccant had been in place for one month.

Fill No.	Barrel 2D (wt. kg.)	Barrel 3D (wt. kg.)
1	1.519	1.536
2	1.451	1.484
3	1.505	1.476
Avg.	1.492	1.499

Table D4
LiOH Average Weight Comparison of Barrels 1, 2, 2D, and 3D

The weights recorded below are the average weights of LiOH required to fill configuration number 1 taken from Tables D2 and D3.

Barrel 1	1.461 kg.
Barrel 2	1.706 kg.
Barrel 2D	1.492 kg.
Barrel 3D	1.499 kg.

Table D5

Configuration 1

Barrel 1			Barrels 2 and 2D		
Test Date	Test No.	Wt. (kg.)	Test Date	Test No.	Wt. (kg.)
Before	41	1.464	3/08/86	59	1.792
3/06/86	45	1.479	3/19/86	55	1.855
"	47	1.445	3/27/86	43	1.634
"	49	1.479	3/27/86	74	1.633
"	53	1.472			
"	57	1.460			

Table D6

Configurations 2 and 5

Barrel 1			Barrels 2 and 2D		
Test Date	Test No.	Wt. (kg.)	Test Date	Test No.	Wt. (kg.)
Before	23	1.162	3/24/86	27	1.302
3/06/86	25	1.136	3/25/86	21	1.288
"	29	1.162	3/26/86	39	1.291
"	31	1.147	3/26/86	73	1.277
"	35	1.185	4/04/86	48	1.256
"	37	1.157			
"	11	1.113			
"	15	1.150			
"	19	1.056			
"	67	1.177			
"	68	1.154			

Table D7

Configuration 3

Barrel 1			Barrels 2 and 2D		
Test Date	Test No.	Wt. (kg.)	Test Date	Test No.	Wt. (kg.)
Before	10	1.595	3/10/86	18	1.923
3/06/86	14	1.596	3/21/86	22	1.833
"	16	1.556	3/25/86	72	1.769
"	20	1.551			

Table D8

Configuration 4

Barrel 1			Barrels 2 and 2D		
Test Date	Test No.	Wt. (kg.)	Test Date	Test No.	Wt. (kg.)
Before	4	3.673	3/07/86	30	4.392
3/06/86	5	3.636	3/12/86	70	4.404
"	6	3.612	3/18/86	26	4.244
"	7	3.635	3/20/86	71	4.012
"	8	3.648			
"	9	3.585			
"	24	3.600			
"	28	3.560			

Appendix E: Phase I-B Data.

Appendix E: Phase I-B Data.

This data may be compared to Phase I data only in relative terms, not directly. The Pc is <u>not</u> the same measurement as the Phase I canister delta P. (the two values were sampled differently).

Split Breathing Bag System
Breathing Resistance (Pc & Pm) and Work of Breathing (WB)
(TESTS WITH LiOH IN CANISTER)

		Depth (fsw)											
		0			100			200			300		
anister Config.	RMV (1)	Pc (cmH2O)	Pm (cmH2O)	WB km/l	Pc (cmH2O)	Pm (cmH2O)	WB km/l	Pc (cmH2O)	Pm (cmH2O)	WB km/l	Pc (cmH2O)	Pm (cmH2O)	WB km/l
(1)	22.5	-0.6	7.	0.04	-0.3	13.	0.09	0.6	23.	0.17	-0.1	29.	0.22
.75 L/D	40.0	1.0	11.	0.07	1.2	28.	0.20	-1.1	45.	0.34	-0.5	60.	0.45
Radial	62.5	1.4	17.	0.11	0.7	53.	0.39	-1.6	86.	0.61	2.3	107.	0.83
200 ci	75.0	-1.6	23.	0.14	-2.5	74.	0.54	1.7	115.	0.85	XXXX	XXXX	XXXX
	90.0	2.8	29.	0.17	3.8	93.	0.68	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
(2)	22.5	0.9	7.	0.04	-0.5	16.	0.12	-0.6	23.	0.17	-0.2	27.	0.30
.25 L/D	40.0	-1.3	12.	0.06	1.2	33.	0.24	-1.6	50.	0.37	0.5	62.	0.46
Radial	62.5	-1.5	18.	0.08	-1.5	61.	0.42	1.8	95.	0.68	1.7	122.	0.89
200 ci	75.0	2.0	19.	0.08	2.9	84.	0.53	-3.5	125.	0.83	XXXX	XXXX	XXXX
-to-out	90.0	-1.8	24.	0.10	2.8	99.	0.62	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
(3)	22.5	0.7	8.	0.04	1.6	16.	0.12	0.6	25.	0.18	0.7	29.	0.21
.25 L/D	40.0	0.2	12.	0.06	3.9	32.	0.23	4.9	51.	0.38	2.8	62.	0.46
Axial	62.5	3.3	20.	0.07	2.3	56.	0.38	6.8	90.	0.65	4.1	115.	0.86
200 ci	75.0	4.9	22.	0.07	9.4	78.	0.49	4.8	124.	0.83	XXXX	XXXX	XXXX
	90.0	7.4	29.	0.07	4.7	95.	0.58	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
(4)	22.5	1.2	8.	0.04	0.7	16.	0.11	0.2	24.	0.17	0.5	31.	0.22
Gortex	40.0	1.9	12.	0.09	1.1	30.	0.21	0.6	48.	0.34	-0.5	62.	0.47
Radial	62.5	1.9	18.	0.09	1.6	57.	0.30	1.2	90.	0.63	1.1	118.	0.84
In-to-	75.0	1.1	21.	0.10	1.8	72.	0.41	-1.2	115.	0.78	XXXX	XXXX	XXXX
Out	90.0	-2.1	26.	0.12	2.0	91.	0.59	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
(5)	22.5	1.2	7.	0.02	-0.2	19.	0.13	0.1	27.	0.19	-0.5	36.	0.26
.25 L/D	40.0	-1.8	13.	0.05	0.2	37.	0.25	-0.5	57.	0.40	1.5	74.	0.53
Radial	62.5	1.3	18.	0.06	0.9	66.	0.42	0.7	104.	0.70	-0.9	133.	0.92
200 ci	75.0	0.4	20.	0.06	-4.5	85.	0.49	-0.2	131.	0.83	XXXX	XXXX	XXXX
t-to-in	90.0	-3.6	25.	0.07	0.7	102.	0.58	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX

ments: (1) Pc = Canister pressure drop
(2) Pm = Mouthpiece pressure drop
(3) XXXX = Data was not recorded due to the high pressures generated at these depths and RMV's.

Single Breathing Bag System
Breathing Resistance (Pc & Pm) and Work of Breathing (WB)

		Depth (fsw)											
		0			100			200			300		
Canister Config.	RMV (L)	Pc (cmH2O)	Pm	WB km/l	Pc (cmH2O)	Pm	WB km/l	Pc (cmH2O)	Pm	WB km/l	Pc (cmH2O)	Pm	WB km/l
(7)	22.5	2.0	6.	0.01	-0.3	17.	0.08	0.8	27.	0.16	0.6	36.	0.23
.75 L/D	40.0	2.0	7.	0.01	0.9	29.	0.12	1.4	49.	0.25	-1.4	67.	0.36
Radial	62.5	3.6	9.	0.01	3.0	40.	0.11	2.8	68.	0.26	-2.1	96.	0.36
200 ci	75.0	-3.0	9.	0.01	-3.6	40.	0.08	4.2	73.	0.11	-3.6	107.	0.22
	90.0	4.9	10.	0.01	5.0	47.	0.04	-6.2	94.	0.11	7.0	124.	0.24
(8)	22.5	0.9	5.	0.01	0.4	12.	0.07	-0.4	22.	0.14	0.4	26.	0.17
.25 L/D	40.0	-1.4	7.	0.01	0.3	22.	0.12	0.8	43.	0.26	0.6	50.	0.34
Radial	62.5	1.9	8.	0.01	2.0	39.	0.15	2.2	68.	0.34	1.0	89.	0.49
200 ci	75.0	1.1	8.	0.01	-2.0	42.	0.13	3.2	73.	0.31	5.3	99.	0.49
-to-out	90.0	1.2	9.	0.01	3.9	52.	0.13	4.7	88.	0.35	6.3	116.	0.55
(9)	22.5												
.25 L/D	40.0												
Axial	62.5												
0 ci	75.0												

mments: (1) Pc = Canister pressure drop
(2) Pm = Mouthpiece pressure drop
(3) Configurations 3, 4, and 5 were not tested with single bag systems.

Phase 1-B
Split Breathing Bag System
Canister Duration in Minutes

		Temperature (deg F)				
		29		40		70
Canister Config.		100 fsw	300 fsw	100 fsw	300 fsw	300 fsw
(1)	Min.	115.0	112.0	171.0	103.0	124.0
	Eff.	0.24	0.21	0.34	0.22	0.27
0.75 L/D	Min.			175.0	104.0	
	Eff.			0.37	0.22	
Radial	Min.		*113.5			
200 ci	Eff.		0.21			
In-to-out						
(2)	Min.	81.0	52.0	*81.5		41.0
	Eff.	0.21	0.14	0.21		0.11
2.25 L/D	Min.	131.3	*31.0		31.0	*41.7
	Eff.	0.37	0.08		0.06	0.10
Radial	Min.	*64.5				
200 ci	Eff.	0.21				
In-to-out						
(3)	Min.	XXXX	213.5	XXXX	221.0	225.0
	Eff.	XXXX	0.56	XXXX	0.42	0.45
2.25 L/D	Min.	XXXX	*145.5	XXXX	223.0	*131.0
	Eff.	XXXX	0.24	XXXX	0.37	0.20
Axial	Min.	XXXX	*145.6	XXXX		
	Eff.	XXXX	0.26	XXXX		
200 ci		XXXX		XXXX		
(4)	Min.	511.2	465.5	492.0	491.0	411.0
Gortex	Eff.	0.48	0.47	0.45	0.40	0.34
Radial	Min.	*294.5	*282.0	451.0	412.0	411.0
Insert,	Eff.	0.20	0.21	0.36	0.34	0.36
2.50 L/D	Min.	*366.0	*293.0			
In-to-Out	Eff.	0.25	0.22			
456 ci						
(5)	Min.	XXXX	25.5		33.0	26.0
2.25 L/D	Eff.	XXXX	0.08		0.07	0.07
Radial	Min.	XXXX	*13.0			25.0
Out-to-in	Eff.	XXXX	0.03			0.07
200 ci		XXXX				

Comments: (1) Min. = Duration in minutes for 0.5% CO2 SEV breakthrough.
(2) Eff. = Effiency of scrubber, lbs. CO2 absorded / lbs. of LiOH in canister.
(3) * = Test done with LiOH from Barrel 2. See Appendix D.

Phase 1-B
Single Breathing Bag System
Canister Duration in Minutes

		Temperature (deg F)		
		40		70
Canister Config.		100 fsw	300 fsw	300 fsw
(8)	Min.		* 21.3	XXXX
	Eff.		0.05	XXXX
2.25 L/D	Min.			XXXX
	Eff.			XXXX
Radial	Min.			XXXX
200 ci	Eff.			XXXX
In-to-out				XXXX
(9)	Min.	XXXX		XXXX
	Eff.	XXXX		XXXX
2.25 L/D	Min.	XXXX		XXXX
	Eff.	XXXX		XXXX
Axial	Min.	XXXX		XXXX
	Eff.	XXXX		XXXX
200 ci		XXXX		XXXX
	Min.			442.0
Gortex	Eff.			0.37
Radial	Min.			
Insert,	Eff.			
2.50 L/D	Min.			
In-to-Out	Eff.			
456 ci				

Comments: (1) Min. = Duration in minutes for 0.5% CO2 SEV breakthrough.
(2) Eff. = Effiency of scrubber, lbs. CO2 absorded / lbs. of LiOH in canister.
(3) * = Test done with LiOH from Barrel 2. See Appendix D.